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SIMULATION OF THE THERMAL LOADS FOR HEATING OF A RESIDENTIAL HOUSE IN MADRID USING MATLAB

Final Thesis

Vilnius, 2015

UNIVERSIDAD CARLOS III DE MADRID

DEPARTAMENTO DE INGENIERÍA TÉRMICA Y DE FLUIDOS

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1. INTRODUCTION

The main objective of the project is to show the thermal loads relating to a town house that is situated in the community of Madrid.

To do this, the first thing you take out is the calculation of the thermal load of the building with the construction features that have been obtained in the planes. It will use the basic equations for heat transfer to conduction, convection and radiation. Differentiation will be made between the heating period, the coldest months of the year, and the period of cooling, the hottest months of the year.

A memory scheme that is presented below, will be the current situation of energy in general and particularly domestic consumption and its environmental influence, then it provides a brief explanation of the physical and mathematical tools and used to calculate housing thermal loads in proceeding further with the calculation of the annual energy consumption in housing is obtained due to the warming of the same. The last step is finding the optimal insulation thickness for physical, economic and respect for the environment.

For these calculations I used MATLAB, an algebraic program, organized as a spreadsheet, where the equations and expressions are displayed graphically. MATLAB (short for MATrix LABoratory, "Matrix Laboratory") is a mathematical software tool that offers integrated development environment (IDE) with its own programming language (language M) and kind service. It is available for Unix, Windows, Mac OS X and GNU / Linux platforms.

Between their basic features are: matrix manipulation, the representation of DATA and functions, implementation of algorithms, creation of user interfaces (GUI) and communication with programs in other languages and other hardware devices.

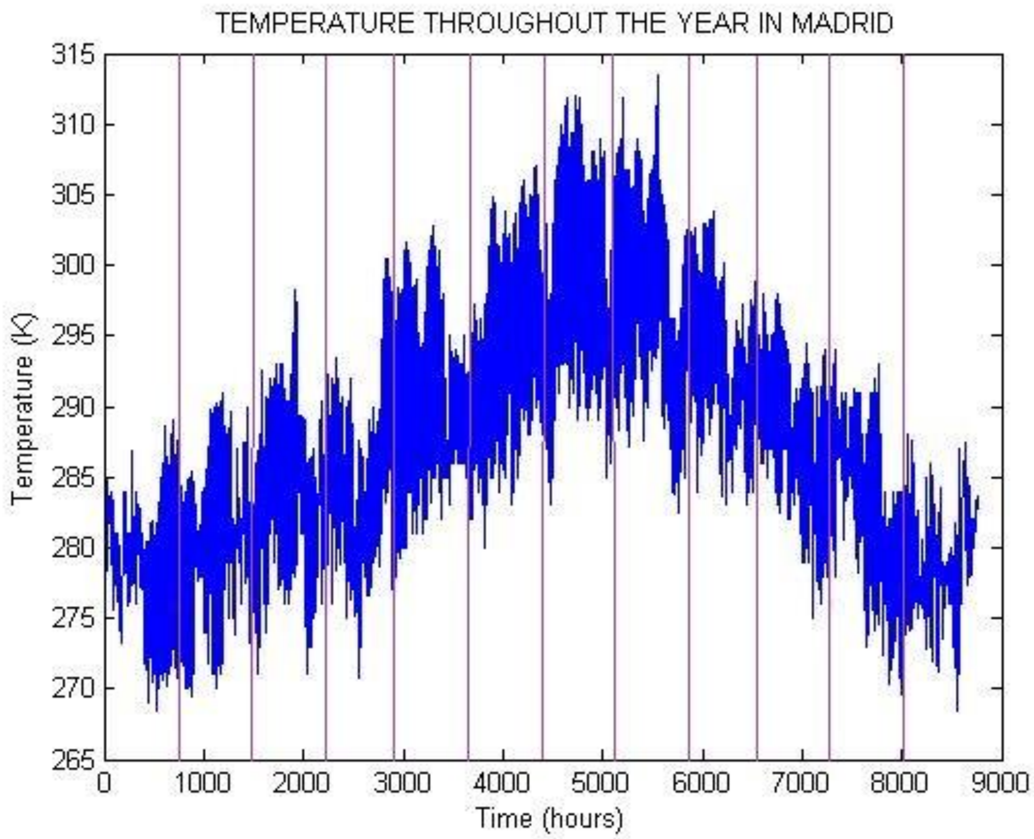
2. CLIMATIC CONDITIONS

To begin with i should remark that all the temperatures and humidities that i use to get this entire graphics are for the year 2013, and corresponding for the city from Madrid.

To study the thermal loads we previously determined parameters. According to the CTE[1] we define a comfortable temperature in winter exceeding 20 degrees Celsius in winter and 25 in summer.

To perform this analysis will have to define an outdoor temperature and outdoor relative humidity, which will change with the passing hours.

Now are shown the diagrams relating to temperature and humidity throughout the year for the two cities chosen. As we will see in the graphic, we have a data for each hour of the year. Therefore we have 8760 data.



[1] CTE : Technical Building Code (in Spanish will be Código Técnico de la Edificación)

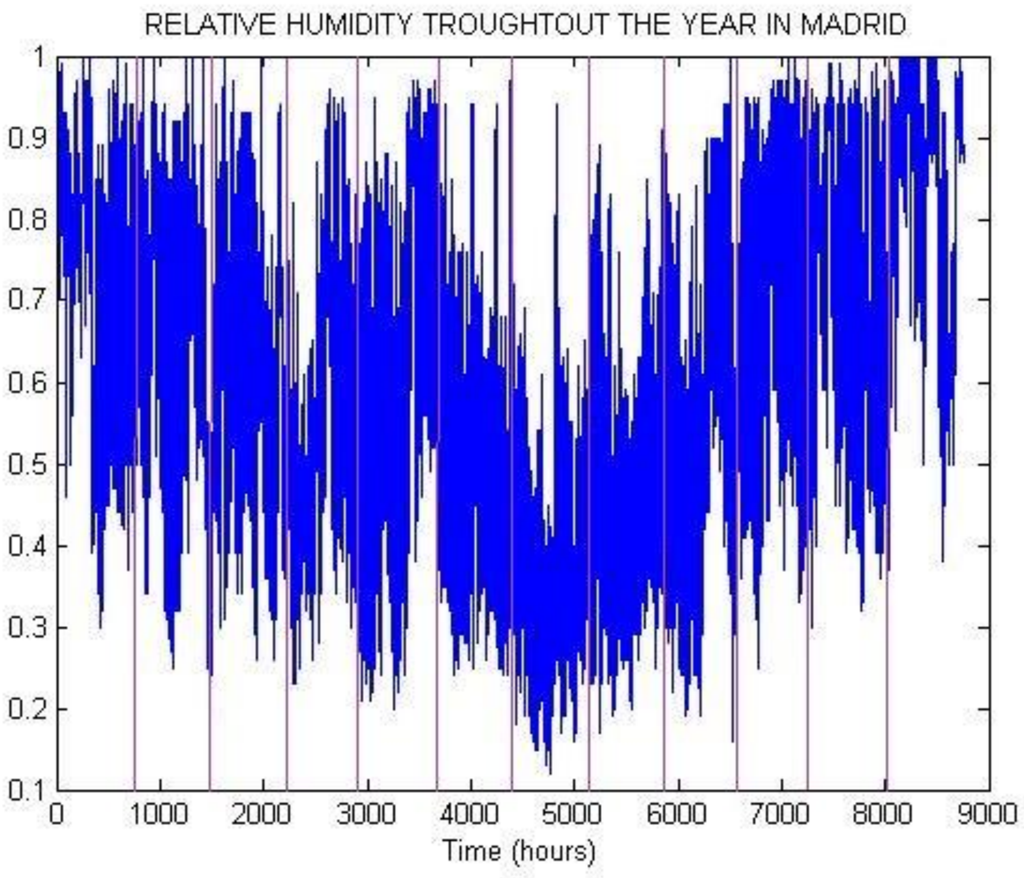
As you can see from now on, thanks to the purple lines that appear in the graphics, we can differentiate between the different months of the year.

To clarify in detail that times are in each month, I made the following table:

JANUARY	1	720
FEBRUARY	720	1440
MARCH	1440	2160
APRIL	2160	2880
MAY	2880	3600
JUNE	3600	4320
JULY	4320	5040
AUGUST	5040	5760
SEPTEMBER	5760	6480
OCTOBER	6480	7200
NOVEMBER	7200	7920
DECEMBER	7920	8760

TABLE 1: Hours for each month

January(1:720h)/February(720:1440h)/March(1440:2160h)/April(2160:2880h)/May(2880:3600h)/June(3600:4320h)/July(4320:5040h)/August(5040:5760h)/ September(5760:6480h)/October(6480:7200h)/November(7200:7920h)/ December(7920:8760h)



As we can see in the graphics Madrid’s climate is a Mediterranean climate. The average temperature is around 15 ºC. The winters are colds with frequent frosts but not as frequent snowfalls. The summers are very warms, and in august and July the temperature can be around of 40 ºC. The annual rainfall is slightly higher than 400mm, with a significant minimum in summer.

The climate of Madrid is a Mediterranean climate and is heavily influenced by urban conditions. According to the criteria of the Koppen climate classification Madrid's climate is classified as a type Csa Mediterranean climate (mild with dry and hot summer) .101 The average temperature (reference period: 1981-2010) is located at of around 14.5 and 15 ° C.

Winters are cold, with average temperatures in the coldest month (January) of around 6 ° C, frequent frosts and rare snowfalls (2 to 5 days of snow a year, depending on the area). This month the mean maximum temperatures barely above 10 ° C, and the minimum range between 0 and 3 ° C. By contrast, the summers are hot. The hottest months are July and August, with July slightly warmer. This month, the average exceeds 25 ° C, with average maximum temperatures between 32 and 33.5 ° C and average minimum temperatures to 19 ° C, down from 17 ° C in the periphery. The daily temperature range is important in the urban periphery (reaching over 13 ° C), but is reduced in the center of the city by the anthropic effect (even down to 10 ° C). The annual temperature range is high (between 19 and 20 degrees, own number of the South Plateau) because of the great distance to the sea and altitude (about 650 meters). Annual rainfall are situated around 400 mm, with a minimum marked in summer (four dry months from June to September) and small oscillations between the urban area, more rainy, and the peripheral area is more arid. The average humidity throughout the year is located around 57 and 58%, with a great oscillation between the much more humid cold weather, and warm, they are very dry. The average wind speed over the year is between 7 and 10 km / h.

3. BUILDING CHARACTERISTICS

3.1 Location

This family house is located in the city of Madrid. The city of Madrid is in the central area of the Iberian Peninsula, a few kilometers north of the Cerro de los Angeles, geographic center of it. The coordinates of the city are 40 ° 26'N 3rd 41'O and its average height above sea level is 667 m, making it one of the highest capitals in Europe.

The geographic and climatic context of Madrid is the southern plateau, in the Central Plateau. The city is located a few kilometers from the Sierra de Guadarrama and hydrographically is located in the Tajo basin.

The Cabrera, a town that is located in the north of the Madrid community, in the region of the Sierra Norte de Madrid, about 56 km from Madrid. The village is situated on the eastern side of the Sierra de La Cabrera with an altitude above sea level of about 1,038 m. The exactly zone where the house will be placed is between the streets Paraguay and Panama.

FIGURE 1: First location of the house (Madrid)

3.3 Building Data

Below appears the plane of the house:

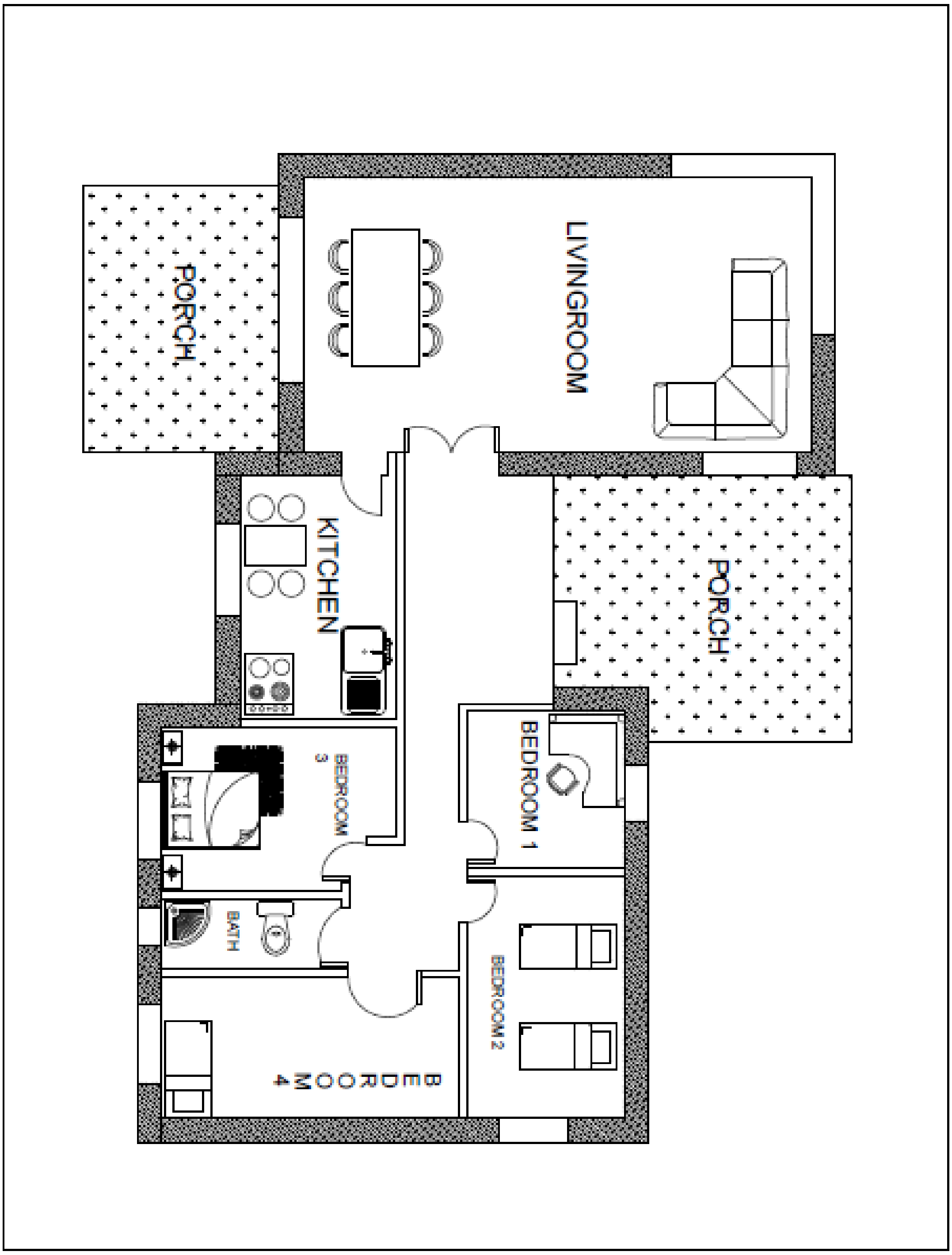


FIGURE 2 : Plane house

The surfaces from the different dependencies, walls, windows and the doors are in the next table:

	Surface (m^2)	*Walls (m^2)*	*Glazed zone S (m^2)*	*Glazed zone E (m^2)*	*Glazed zone N (m^2)*	*Glazed zone O (m^2)*	*Door (m^2)*
LIVINGROOM	**47.77**	**47.33**	**6.05**	**7.11**	**---**	**6.05**	**2**
BATHROOM	**5.36**	**3.86**	**---**	**0.36**	**---**	**---**	**---**
KITCHEN	**11.36**	**10.41**	**---**	**2.31**	**---**	**---**	**---**
BEDROOM 1	**10.33**	**14.68**	**---**	**---**	**---**	**2.59**	**---**
BEDROOM 2	**13.64**	**19**	**---**	**---**	**2.59**	**---**	**---**
BEDROOM 3	**10.80**	**9.63**	**---**	**2.59**	**---**	**---**	**---**
BEDROOM 4	**15**	**20.16**	**---**	**2.59**	**---**	**---**	**---**
HALL	**14.74**	**3.91**	**---**	**---**	**---**	**---**	**4.80**

TABLE 2: Surface from different dependencies

We already know the composition from the walls, cover and soil, except the thickness of the insulating material. The data from the composition of the thickness and the conductivity of each the cladding layer is as follows:

OUTER WALL		
composition	thickness (m^2)	k(W/mk)
cement mortar	**0.02**	**1.14**
hollow brick	**0.09**	**0.52**
polystyrene	**---**	**0.04**
hollow brick	**0.09**	**0.52**
plaster	**0.02**	**0.30**

TABLE 3: Outer wall composition

ROOF		
composition	thickness (m^2)	k(W/mk)
cement with aggregates	**0.05**	**1.16**
concrete slab	**0.25**	**1.39**
polystyrene	**---**	**0.04**
plaster	**0.02**	**0.30**

TABLE 4: Roof composition

FLOOR		
composition	thickness (m^2)	k(W/mk)
sand filling	**0.05**	**0.50**
stone	**0.35**	**1.83**
concrete slab	**0.45**	**1.63**
wood	**0.07**	**0.14**

TABLE 5: Floor composition

4. HEAT TRANSFER

By the studying of the heat transfer we can obtain the results like the heat loss through the wall or window of the house, the influence of solar radiation, etc.

The heat transfer is defined like “thermal energy in motion due a temperature difference". This energy in motion arises from a fuel that when it burns becomes into a type of energy that is capable of heat a home, among many other things.

Below we are going to study the different heat transfer modes.

4.1 Conduction

To properly explain the term conduction, we must resort to concepts such as molecular activity. Using these concepts driving the phenomenon can be explained as "transfer of energy from the most energetic particles to less energetic particles, of a material due to interactions between the particles" .

The physical explanation of driving is easily explained considering a gas occupying a space between two surfaces that are maintained at different temperatures. The higher temperature causes the particles near the surface start moving in a random fashion, and collided with colder particles and get that this could increase this movement of translation and rotation, so they get to increase their energy, getting transferred the heat from the hot surface to the cold. At higher temperature, a higher molecular associated power and when there is a collision with a neighboring particle with less energy there is a transfer of energy from more energetic to less energy particle. This phenomenon is explained in gases, is the same for in liquids and solids, the difference is that the molecules are closer each other, whereby heat transfer entail fewer losses.

It is possible to quantify the heat transfer processes, leading to calculate the amount of energy transferred per unit of time driving. For conduction phenomenon known as Fourier's Law and the equation is as follows:

$$q"_x = -k\frac{dT}{dx}$$

Equation 1

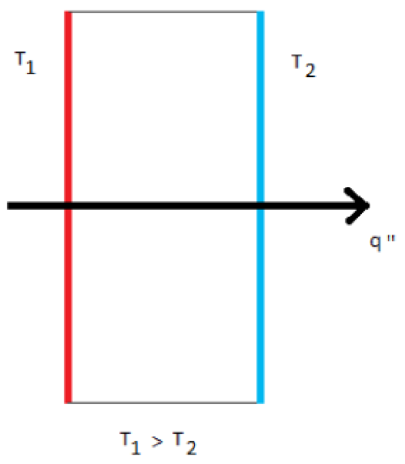


FIGURE 3 : Phenomenon of conduction through a solid

This equation represents the heat flux, is the heat transferred in the x direction per unit direction perpendicular to the transfer area, and is proportional to the temperature gradient in this direction. The parameter k is a material transporting property known as the thermal conductivity (W/mK). The symbol (-) represents that heat is transferred in the direction of decreasing temperature.

4.2 Convection

The phenomenon of heat transfer for convection is composed of two mechanisms. In addition to molecular diffusion transfer energy is transferred by a macroscopic phenomenon, or movement of a fluid. This movement of fluid contributes to the heat transfer in the presence of a thermal gradient. The molecules are in a fluid energy retains its molecules and thus this phenomenon is the sum of convection and thereby retaining energy by the fluid. Especially interesting existing heat transfer between a fluid and a surface moving when they are at different temperatures.

The heat transfer of convection can be classified according to the nature of the flow that strikes the surface. It will be natural convection when the fluid it moves with no external factor.

The equation that describes this process has the same way:

$$q" = h(T_s - T_\infty)$$

Equation 2

This equation is known as the Newton 's law of cooling. the convection coefficient , h , depends on the geometry of the surface , the nature of motion of a set fluid and thermodynamic properties of the fluid.

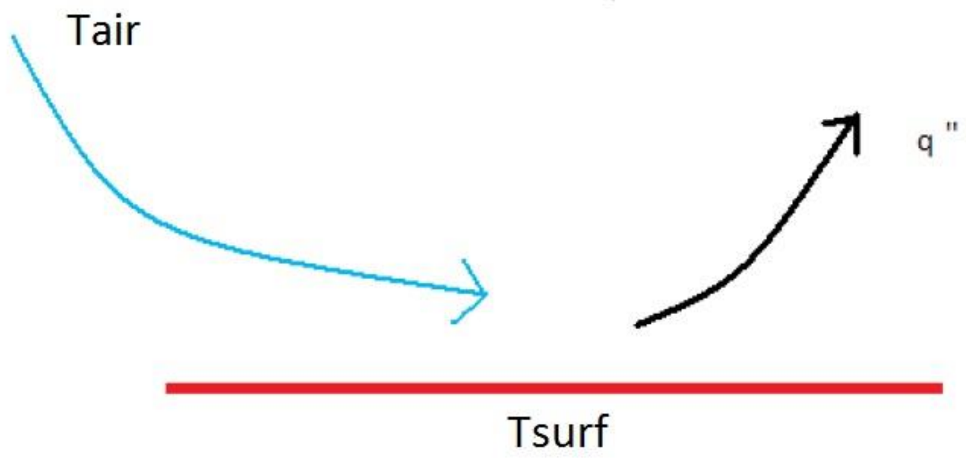


FIGURE 4: Surface of convection of a flowing fluid.

4.3 Radiation

The radiation phenomenon is defined as "energy emitted by matter that is at one temperature that is greater than zero". This radiation occurs in all types of surfaces: solids, liquids and gases. This issue can be attributed to changes in the configurations of electrons from atoms or molecules that constitute matter. The radiation energy is communicated via electromagnetic waves alternately photons. Of the three heat transfer phenomena it is the only one who does not need the presence of a material medium for transport, in fact, is more effective when radiation is when the transfer occurs in a vacuum.

The speed at which a surface emits energy as electromagnetic radiation depends on the temperature and nature of said surface. When radiation is incident on a body can be partly absorbed, partly reflected and transmitted depending on the surface. Generally these fractions depend on temperature and the nature of the surface.

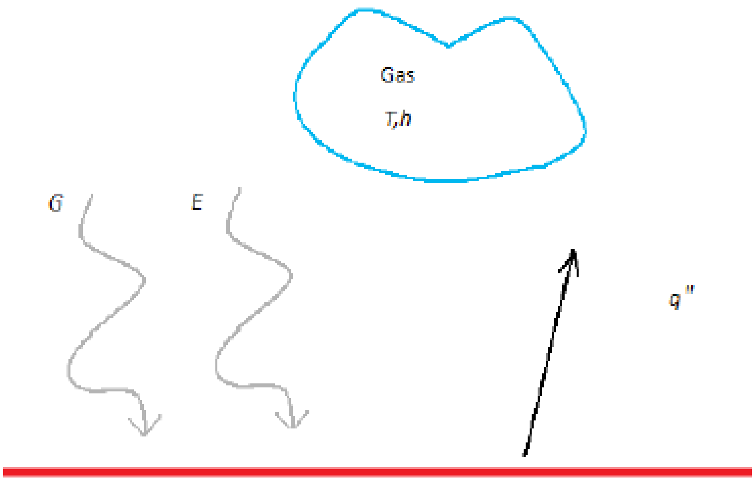


FIGURE 5 : Radioactive heat transfer from a surface

The heat flow emitted by a real surface is always smaller than that of a black body at the same temperature. The black body is a borderline case, in which the entire incident energy from the outside is absorbed, and the whole incident energy is emitted from the outside, but there is in nature a black body. The black body can be approximated as a cavity with a small opening. There is a limit to the emitted power is described in the following equation which is known as the Steffan-Boltzmann law, which describe the behavior of the above-described black body.

$$E_b = \sigma \cdot T_s^4$$

Equation 3

Where σ is the Stefan-Boltzmann constant ($\sigma = 5.67 \cdot 10^{-8}$ W / $m^2 \cdot K$) and the temperature T is the absolute temperature of the body.

But we must emphasize that the heat transfer radiation emitted by the surface is described by the following equation:

$$E = \sigma \cdot \varepsilon \cdot T_S^4$$

Equation 4

Where ε is a property called emissivity surface. Its value is between 0 and unity and gives an idea of how efficient the surface in relation to the black body. This ratio is closely linked to the surface and the surface finish of the material.

Radiation may also be incident on the surface from the surroundings, this radiation irradiation is called, and is called by the letter G. A portion of the irradiation is absorbed by the increasing thermal energy surface thereof. The ability of the material to absorb the radiated energy from outside is called absorptivity (α) whose value ranges from 0 to 1, and the absorbed energy is represented by:

$$G_{abs} = \alpha \cdot G$$

Equation 5

The expression indicating the flow of heat transferred by radiation is the difference between the energy emitted by the surface and winning due to absorption of radiation.

5. CALCULATING THE THICKNESS OF POLYSTYRENE

In this section I will calculate the thickness required for both the roof and the exterior wall, of expanded polystyrene. I'll start with the calculation of the thickness of the roof. Convection resistances vary if we are in summer or winter, as heat will flow in opposite directions. We will take the worst case, to ensure good insulation do all year. Therefore convection resistances on the cover for the winter season are according the Technical Code Edification Spanish (CTE):

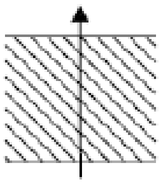
position and the inner partition of the heat flow direction	Rse	Rsi
interior horizontal or sloping on the horizontal <60 partitions and up flow 	0.04 m^2k/w	0.13 m^2k/w

TABLE 6: Enclosing surface thermal resistances upward heat flux

$$\begin{cases} Rse = 0.04\ m^2k/w \\ Rsi = 0.10\ m^2k/w \end{cases}$$

D3 CLIMATIC ZONE

- Limit transmittance of walls and facades contact with the ground $\longrightarrow$ U_{Mlim} : 0.66 W/m^2K
- Limit transmittance of floors $\longrightarrow$ U_{Slim} : 0.49 W/m^2K
- Limit transmittance of the roof $\longrightarrow$ U_{Clim} : 0.38 W/m^2K
- Solar factor $\longrightarrow$ F_{Llim} : 0.28

% surface hollows	Limit transmittance hollows				Solar factor					
					Low internal load			High internal load		
	N	E/W	S	SE/SW	W/W	S	SE/SW	E/W	S	SE/SW
0 to 10	3.5	3.5	3.5	3.5	-	-	-	-	-	-
11 to 20	3.0(3.5)	3.5	3.5	3.5	-	-	-	-	-	-
21 to 30	2.5(2.9)	2.9(3.3)	3.5	3.5	-	-	-	0.54	-	0.57
31 to 40	2.2(2.5)	2.6(2.9)	3.4(3.5)	3.4(3.5)	-	-	-	0.42	0.58	0.45
41 to 50	2.1(2.2)	2.5(2.6)	3.2(3.4)	3.2(3.4)	0.50	-	0.53	0.35	0.49	0.37
51 to 60	1.9(2.1)	2.3(2.4)	3.0(3.1)	3.0(3.1)	0.42	0.61	0.46	0.30	0.43	0.32

TABLE 7: Climate Zone D3

According with the Spanish technical code edification, Madrid belongs to the zone D3, so his U lim will be 0.49 W/m^{2}k.

Conduction resistances were calculated as Rcond = $\frac{thickness}{k}$

Equation 6

The equivalent thermal circuit associated to the wall of the family house is that shown in the following figure:

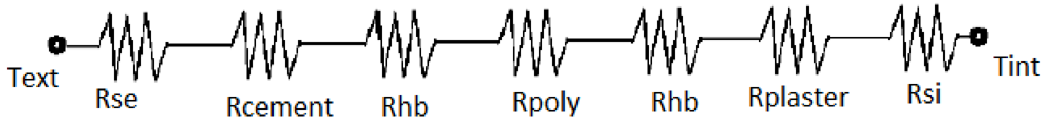


FIGURE 6 : Thermal equivalent circuit

In addition to the resistances shown above are used often many others that their values can be obtained in experiments such as contact resistances, due to contact between two surfaces and gaps that may occur between them, or other like example due to fouling, fouling resistance, which can increase over time as dirt accumulates for example in a tube and that means that there is a new resistance that was previously not or is variable with time.

We also know that Urof.lim $=\frac{1}{R_t}$, being Rt the sum of all the resistances of convection and conduction.

total resistance is referred to the sum of the thermal resistances of the wall. Sometimes they can be distributed either in series or in parallel thermal resistances, to solve this problem there are different ways to add resistance, but in the case study all the resistances are addressed in series, so that a sum of the resistances is how to solve the problem.

For the resolution of the problem of heat loads in the building the first thing that has to be done is to calculate the overall heat transfer coefficient in all types of surfaces susceptible to heat transfer between them and the outside. To do so, the theory discussed above both thermal resistances as the use of global coefficient of heat transfer and following the guidelines of the technical building code, basic document of energy savings is calculated the overall coefficient of heat transfer in the areas susceptible to heat exchange.

ROOF			
composition	thickness (m^2)	k(W/mk)	resistance
cement with aggregates	**0.05**	**1.16**	**0.043**
concrete slab	**0.25**	**1.39**	**0.179**
polystyrene	**---**	**0.04**	**---**
plaster	**0.02**	**0.30**	**0.067**

TABLE 8: Roof resistances

Table considering the thicknesses set forth above and solving formulas we can easily find that the required thickness of polystyrene so that these specifications are met is of:

- **Thickness of polystyrene of the roof = 0.031m**

As the outer wall heat fluxes also vary in summer or winter, but the sum of values of the resistors convection is the same. The values for these resistors according to the CTE are:

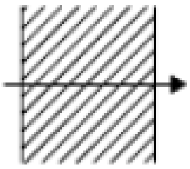
position of the enclosure and heat flow direction	**Rse**	**Rsi**
vertical or horizontal hanging over > 60º enclosures and horizontal flow 	0.04 m^2k/w	0.10 m^2k/w

TABLE 9: Resistances enclosing surface in contact with the outside

Rse = 0.04 m^2k/W Uow.lim = 0.66 W/m^2k

Rsi = 0.13 m^2k/W

OUTER WALL			
composition	thickness (m^2)	k(W/mk)	resistance
cement mortar	**0.02**	**1.14**	**0.017**
hollow brick	**0.09**	**0.52**	**0.173**
polystyrene	**---**	**0.04**	**---**
hollow brick	**0.09**	**0.52**	**0.173**
plaster	**0.02**	**0.30**	**0.067**

TABLE 10: Outer wall resistances

Solving formulas, we calculate that the required thickness of polystyrene so that these specifications are met in the outer wall, is:

- **Thickness of polystyrene of the outer wall = 0.024m**

6. THERMALS LOADS

For the study of thermal loads will proceed calculating the same in the winter period where the Regulation of Thermal Installations in Buildings (RITE) brand conditions inside operating temperature between 20 and 23 degrees Celsius and a relative humidity between 40 and 50 % .

To carry out this analysis will have to define a temperature and outdoor relative humidity that are changing depending on the day that they are. For it will have to define both vectors, with real data on temperature and relative humidity for good accuracy are taken for each hour of the year. Thus the outside temperature will have on the environment of housing in every hour of the year and relative humidity. Thus calculations can be made for each hour later being able to appreciate the different thermal loads, to come differentiated by time of year and can make a more accurate study.

6.1 Thermal transmission loads

Along this section we will calculate the thermal load transmission through the cover, exterior wall, window, door and floor. The thermal transmission loads is sensitive loads, due solely to the difference in temperatures, transmitted to the interior of the house by conduction through the various enclosures. This load is calculated by the next formula:

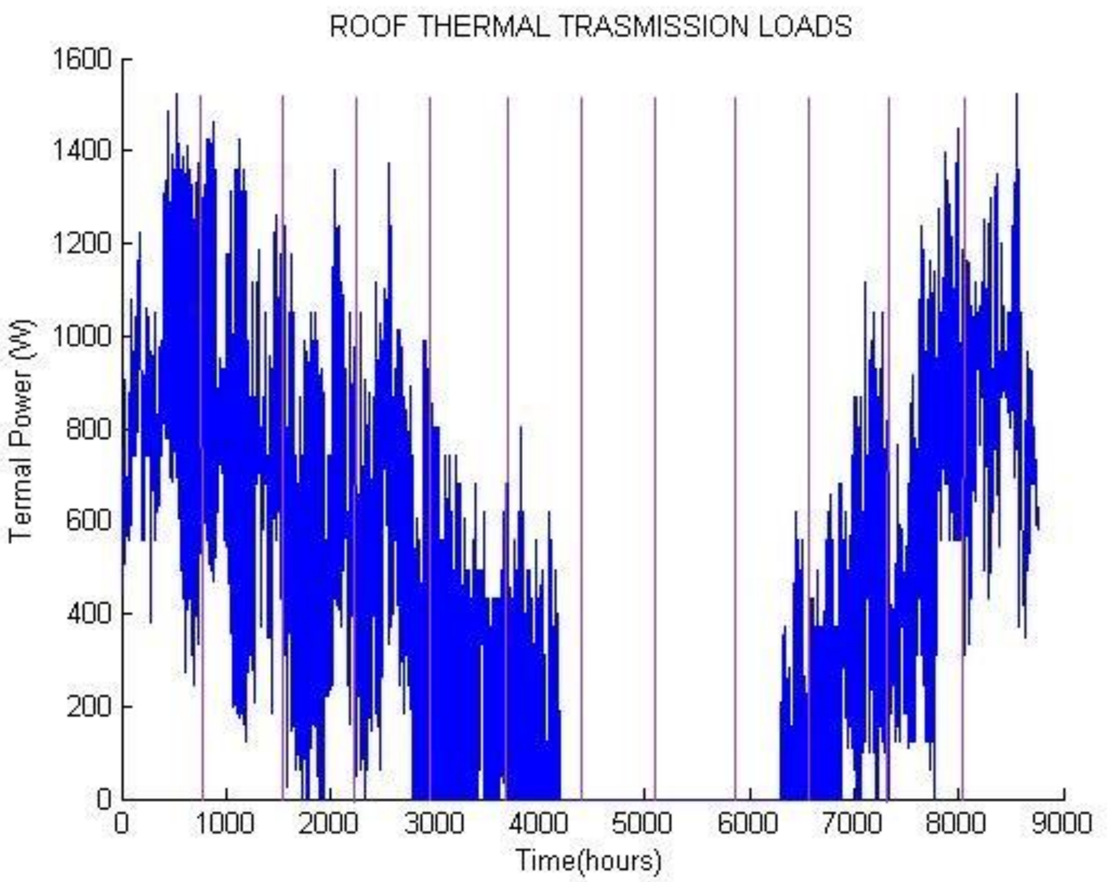
$$Q_{transmission} = U_{enclosures} \cdot A_{enclosures} \cdot (T_{INT} - T_{EXT})$$

Equation 7

We note that the interior temperature for the winter period will be 20 ° C, while for summer reach 25ºC. Outside temperatures will vary one time at the different hour, as can be seen in section 1. The value of the overall coefficient of heat transfer limit indicated by the corresponding CTE to the deck, for the area in which is located the city of Madrid it has a value of 0.49 W / m^2 · K.

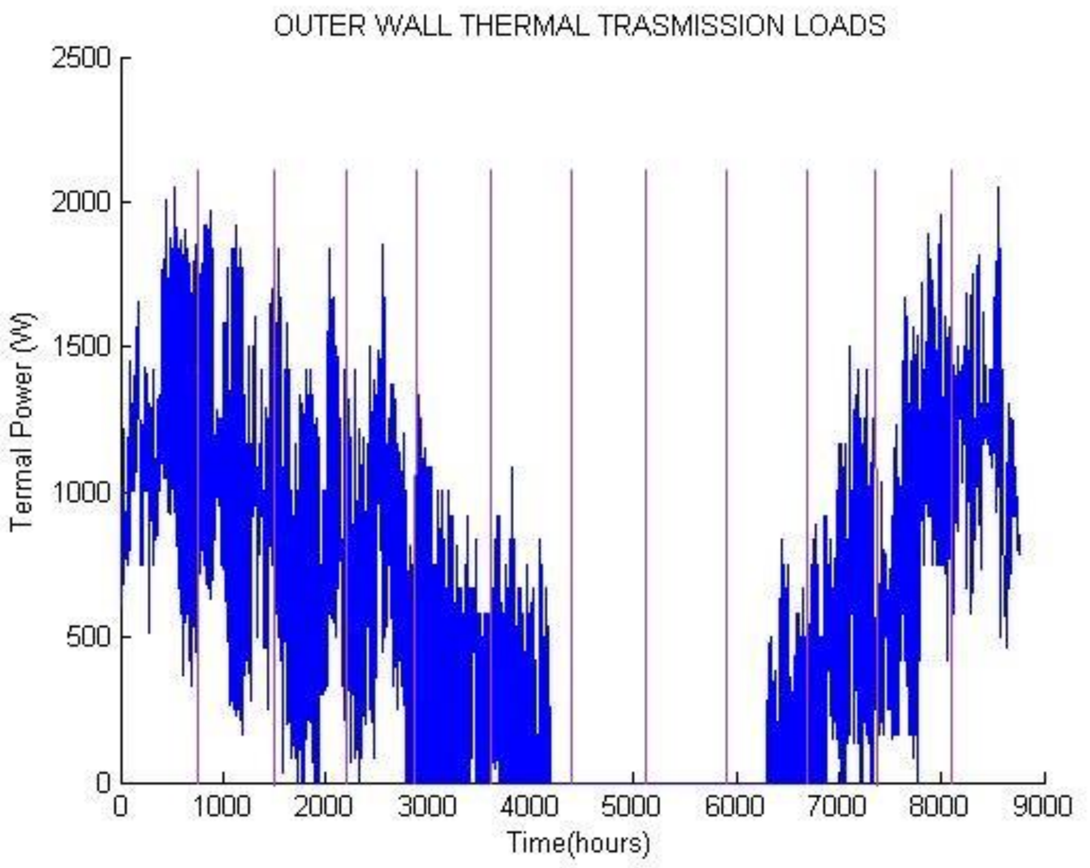
To model this heat load, will have to go see one by one all the components, since for all the indoor and outdoor temperatures are the same, per both the overall heat transfer coefficient as the surface covering varies. Removed the values for acclimatization period, for both heating period this range have a value of zero.

The graph shown below refers to thermal loads transmitted through the cover. The blue color is that of heating, while the red color corresponds to the cooling.



January(1:720h)/February(720:1440h)/March(1440:2160h)/April(2160:2880h)/May(2880:3600h)/June(3600:4320h)/July(4320:5040h)/August(5040:5760h)/ September(5760:6480h)/October(6480:7200h)/November(7200:7920h)/ December(7920:8760h)

To study the thermal loads we have to determine two seasons, but actually we note that these do not refer to winter and summer seasons. I chose the start of the cooling season this time around 4200, and the heating season begins in 6300, corresponding to the 10th of October.



January(1:720h)/February(720:1440h)/March(1440:2160h)/April(2160:2880h)/May(2880:3600h)/June(3600:4320h)/July(4320:5040h)/August(5040:5760h)/ September(5760:6480h)/October(6480:7200h)/November(7200:7920h)/ December(7920:8760h)

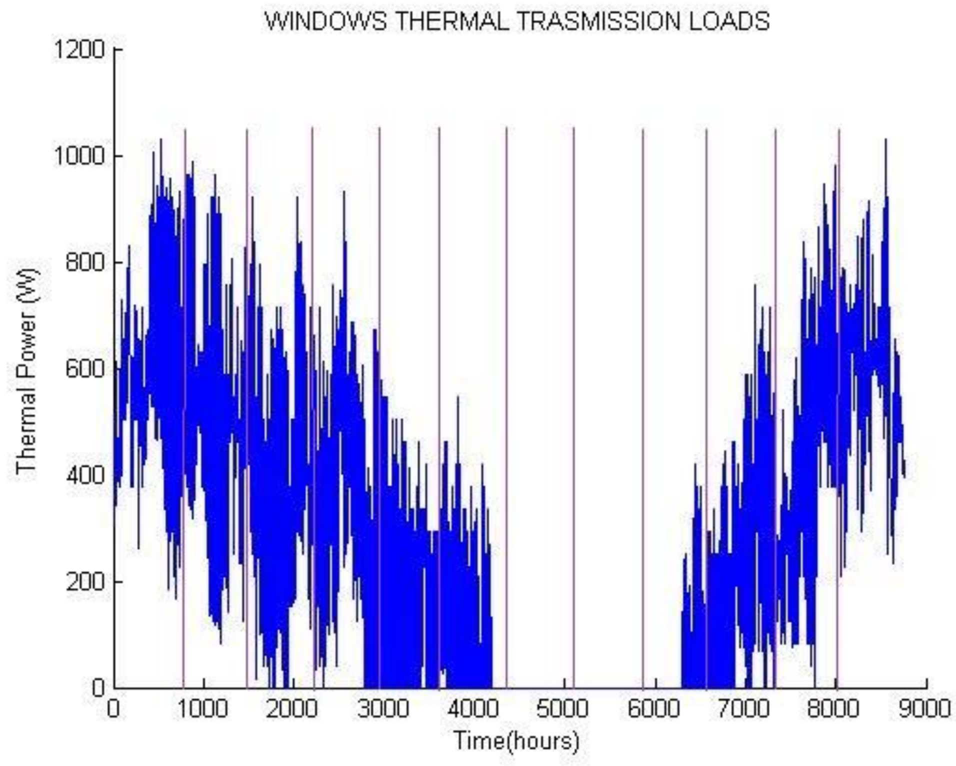
As indicated the CTE, the value of overall heat transfer coefficient boundary indicated by the CTE for the wall, has a value of 0.66 $W / m^2 \cdot K$.

As we as we can see in the CTE the overall heat transfer coefficients are assumed known and equal a 1.3 $W/m^2 \cdot K$ y 1.5 $W/m^2 \cdot K$, respectively.

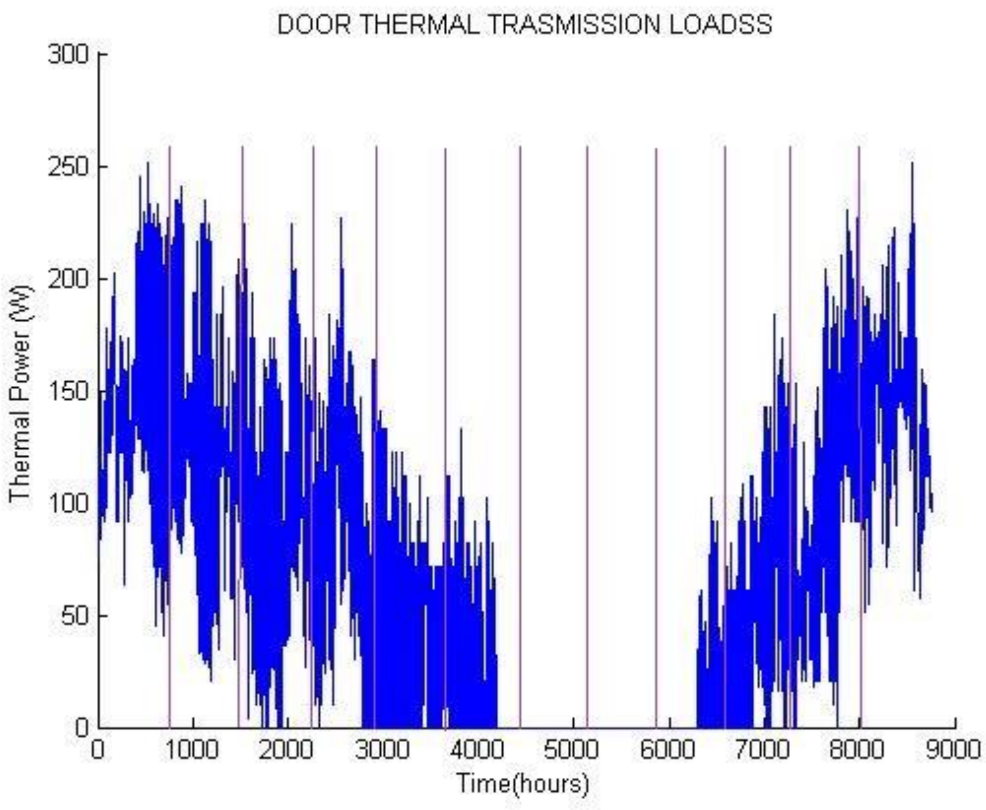
Transmission thermal loads through the wall, like the transmission through the cover, acquire much higher values in the winter season. I must emphasize that this burden also takes higher values in the wall on the deck. The insulation thickness calculated in paragraph two on the wall is less than in the cover. Lose more heat through the walls of the wall.

As you can see all the values of the graph are greater or equal to zero, since the negative charges are canceled to be favorable to our climate.

The higher heating loads, as expected occur in the months of January and December.



January(1:720h)/February(720:1440h)/March(1440:2160h)/April(2160:2880h)/May(2880:3600h)/June(3600:4320h)/July(4320:5040h)/August(5040:5760h)/ September(5760:6480h)/October(6480:7200h)/November(7200:7920h)/ December(7920:8760h)



The first thing that we have to remind is that the contribution of the thermal load through the floor is going to be considering only in the heating period. To calculate the heat load provided by the floor of the house we need to do a previous study of the use of basement of the house. This lower part of the house is used as the garage, so it will not be necessary refrigerate or heat this area because it was not live. Therefore, in this entire area there is a temperature for the heating period that it will be the one that is in contact with the floor of the house. The way in which is estimated the garage temperature is the midpoint between soil temperature and indoor comfort temperature. As both the indoor temperature and the ground temperature are constant in the heating period, contribution of thermal load will be constant for all times of the year. The temperature of the ground in the locality where the property is located is 5^{o}C that by averaging the temperature inside Living comfort we obtain a value for the garage's temperature of 12, 5^{o}C.

Another element that has to be studied is the windows of the house. In the house there were two window types differentiated by the type of insulation crystal. One type was in the garage, small dimensions and other were in the house, where it will make life inside the house. The latter are to be taken into account in the study because, as discussed above, the garage will not be heated and those little windows do not influence the thermal load.

In the same way as with the windows, the doors the same case of heating the garage not be necessary, therefore not have to use data from the same door.

6.2 Thermal ventilation loads

Below i am going to calculate the ventilation thermal loads.

The charges relate to the renewal the indoor air by outside air. To avoid the unpleasant sensation that elicits the stale air is necessary to introduce a certain amount of outside air vent is called. The burden of ventilation is the derivative of this renewal of the air inside the house. The total ventilation load will have his contribution both latent heat and sensible heat. The equations that I used are:

$$Q_{sensible\ ventilation} = V_{air} \cdot \rho_{air} \cdot Cp_{air} \cdot (T_{int} - T_{ext})$$

Equation 8

$$Q_{latent\ ventilation} = V_{air} \cdot \rho_{air} \cdot h_{fg\ water} \cdot (\omega_{int} - \omega_{ext})$$

Equation 9

You can determine the ventilation air flow using the minimum flow required in the technical building code. These flows are distinguished in liters per second of air that depends on the number of people living in the house, or the area occupied by the different rooms of the house. The figure below shows these required minimum flows that have been used to calculate the flow of ventilation.

		minimum ventilation flow demanded q_v , in l/s		
		per occupant	Per m^2 useful	depending on other parameters
LOCAL	Bedroom	5		
	Living room	3		
	Bathroom			15 per local
	Kitchen		2	50 per local
	Common areas		0.7	
	Parking			120 per parking space
	waste storage		10	

TABLE 11 : Flow demanded

For air flow ventilation i will use the CTE in it we can see the minimum required flow rates. We consider in our home 5 people live, so for our house the airflows are:

LIVINGROOM	5persons	15(l/s)
BATHROOM	---	15(l/s)
KITCHEN	11.36m^2	22.72(l/s)
BEDROOM1	1 persons	5(l/s)
BEDROOM2	1 persons	5(l/s)
BEDROOM3	1 persons	5(l/s)
BEDROOM4	2persons	10(l/s)
HALL	14.74m^2	10.46(l/s)

TABLE 12: Flow Rates

I need to know the saturation pressure for different outdoor temperatures that I have. After calculating this I can determine the value of the external absolute humidity. Below i am going to explain, with a series of mathematical relationships, as we have reached the final equation, thanks to which we can calculate the thermal loads due to air exchanges.

As we know:

$$\dot{m}_a = \dot{V}_a \cdot \rho_a$$

Equation 10

We have a mix of air and vapor. Now we will use Dalton's Law:

$P = \sum P_{Pi}$; being P_{Pi} the partial pressures

Equation 11

$P = P_{PV} + P_{Pa}$, where P_{PV} is the partial vapor pressure and P_{Pa} the partial air pressure.

Hypothesis

AIR (ideal gas) $\longrightarrow$ $P_{Pa} \cdot V = m_a \cdot R_{ga} \cdot T_a$

Equation 12

VAPOR (ideal gas) $\longrightarrow$ $P_{Pv} \cdot V = m_v \cdot R_{gv} \cdot T_v$

Equation 13

Relative Humidity (RH), $\Phi = \frac{P_{Pvap}}{P_{sat}(T)}$

Equation 14

Relative humidities, $\omega = \frac{m_v}{m_a}$

Equation 15

Gas constant (Rg), $R_g = \frac{\bar{R}}{MW}$ $\longrightarrow$ $\bar{R} = 8.314\ J/mol \cdot K$

$\longrightarrow$ Molecular Weight

The volume they occupy is the same, according to Dalton's law. They behave as if they occupied all the space.

$$\frac{P_{Pv} \cdot V}{P_{Pa} \cdot V} = \frac{m_v}{m_a} \cdot \frac{R_{gv}}{R_{ga}} \cdot \frac{T_v}{T_a}$$

$$\omega = \frac{R_{gv}}{R_{ga}} \cdot \frac{P_{Pv}}{P_{Pa}} = \frac{R_{gv}}{R_{ga}} \cdot \frac{P_{Pv}}{P - P_{Pv}} = \frac{R_{gv}}{R_{ga}} \cdot \frac{\Phi \cdot P_{sat}(T)}{P - P_{sat}(T)}$$

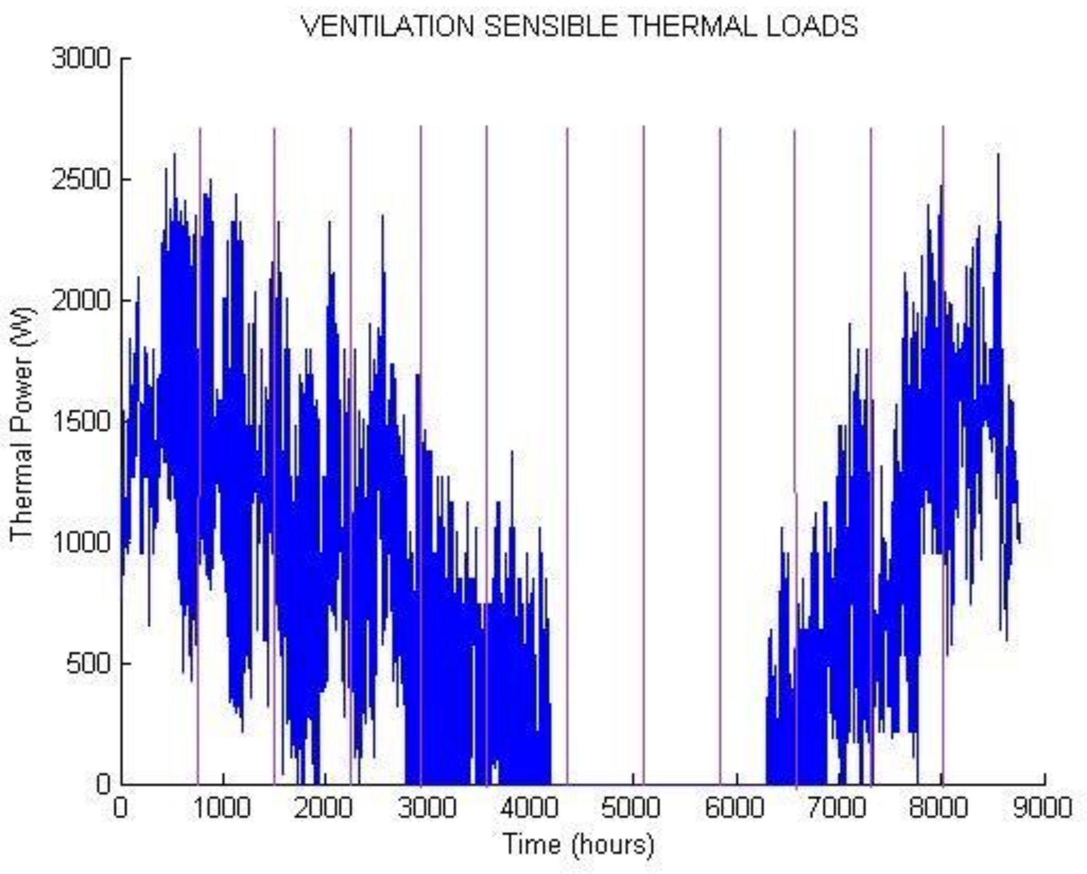
$$\omega = \frac{\bar{R}/MW_a}{\bar{R}/MW_v} \cdot \frac{\Phi \cdot P_{sat}(T)}{P - P_{sat}(T)} = 0.622\ \frac{\Phi \cdot P_{sat}(T)}{P - P_{sat}(T)}$$

Equation 16

Finally we achieve the equations that we are going to use:

$$\omega_{ext} = 0.622 \cdot \frac{\phi \cdot Psat(T)}{P - \phi \cdot Psat(T)} \qquad \text{Psat(T)} = 2.368745 \cdot 10^{11} \cdot e^{\frac{-5406.1915}{Text}}$$

Equation 17 **Equation 18**



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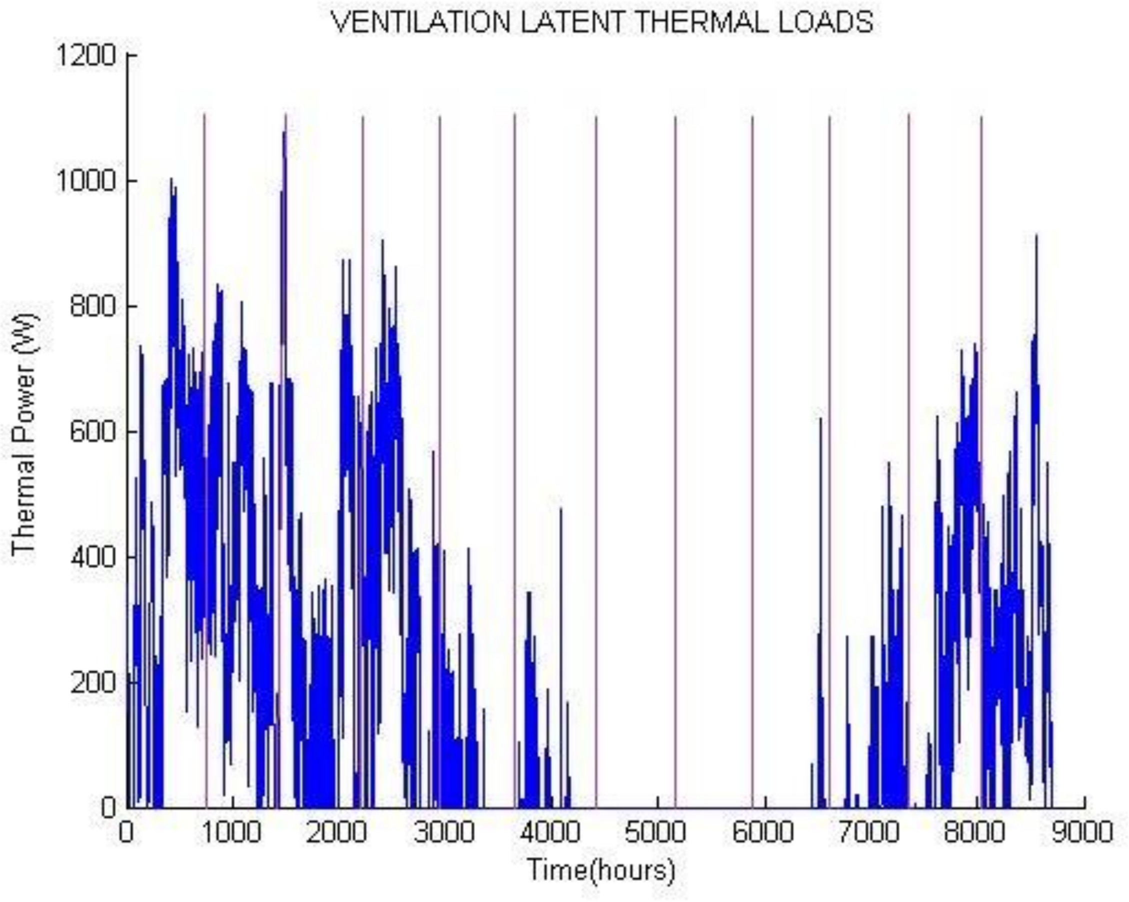
As indicated in the above formulas, the ventilation loads, both sensible and latent, it has as a priority component , the relative humidity. It is easy to deduce that the greatest burdens of sensitive ventilation going to find in the winter months, i.e. January and December, because in these months we can find the highest values of relative humidity. These values will decrease as we move into the year, because in the hottest months we will have a lower relative humidity values.



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As would be expected, in the graph of ventilation latent loads, we have the same behavior as in the graph of sensitive ventilation. Are the winter months which provide a greater burden on the total sum. However, as noted, this year in particular, there was a peak for the month of February. It is in this month that we find the greatest value, next to 1100 W.

The greatest influence on the ventilation heat load is due to sensible heat, since according to the hours between other things the temperature difference is greater than the difference in humidity around 33% being due to the flow created by the difference of relative humidity and 66% due to the temperature difference in the contribution to the heat load due to ventilation.

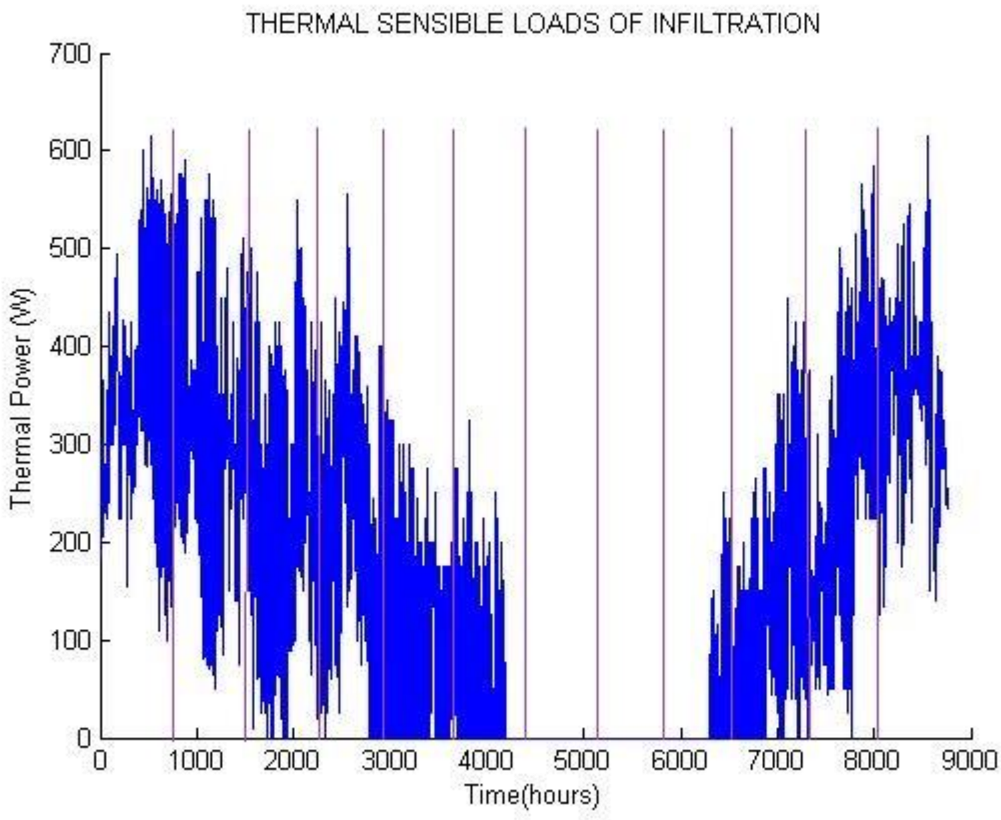
6.3 Thermal infiltrations loads

The infiltration of outside air into an air-conditioned local is produce always when the local is a lower pressure than the surrounding environment. The infiltrations produce different effects as the introduction of cold in the heating period or warmth cooling period in the indoor environment, can also be introduced into the local as dust and contaminants outdoor and water vapor, resulting in latent load.

Infiltrations and in particular the entry of water vapor, are an important source of heat gain or loss. The air flow varies infiltration sealing doors and windows, the porosity of the building walls, their height, and direction, among many others. Sometimes, many of those dependent parameters can not be calculated and must be subject to more or less empirical estimation.

Infiltration through doors and windows during the winter is due to the dynamic pressure of wind and stack effect, which is the name given to the density difference between the outside air and the interior caused by differences in humidity and temperature. Outside air enters through the lower parts, heated inside, amounts and evacuated by the high parts, giving a movement of natural circulation.

Below we can see the thermal infiltration loads. These loads are the result of the heat input during the summer or the entry of cold during the winter. One effect of this process is the water vapor input, which influence the latent load. This will be a major source of heat gain or loss. The air flow varies infiltration sealing doors and windows. For its calculation we will consider that in the windows the infiltration rate is 1.3 $\frac{W}{m^2K}$ and the door is 1.5 $\frac{W}{m^2K}$.



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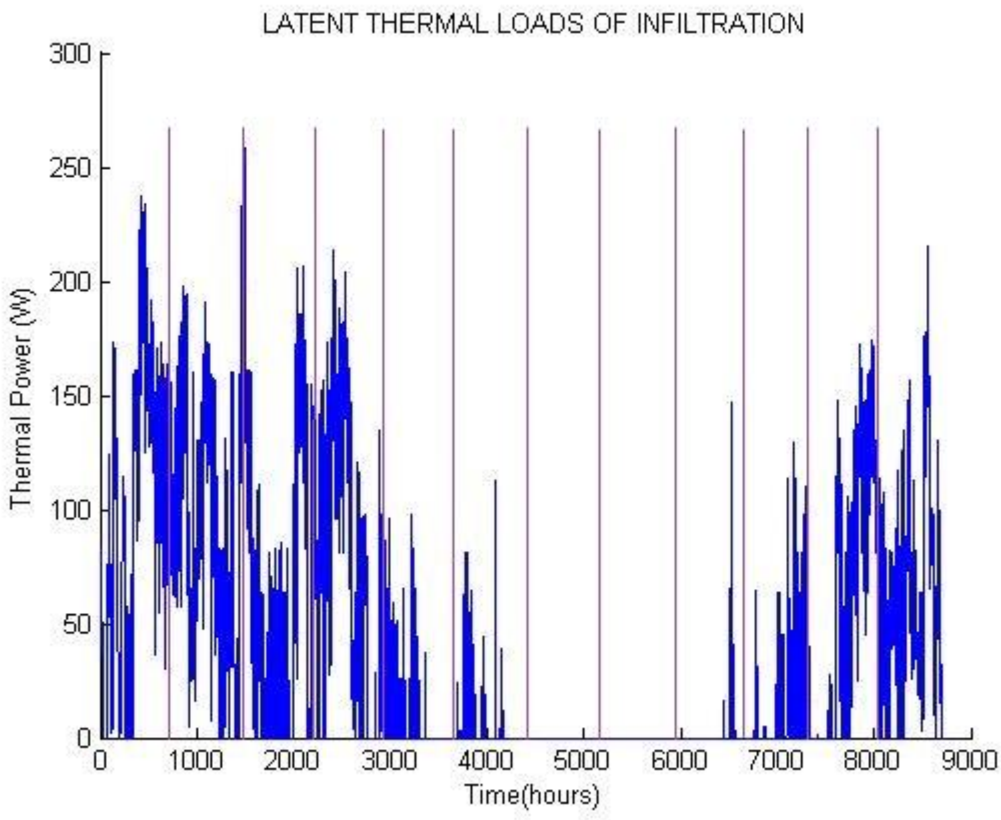
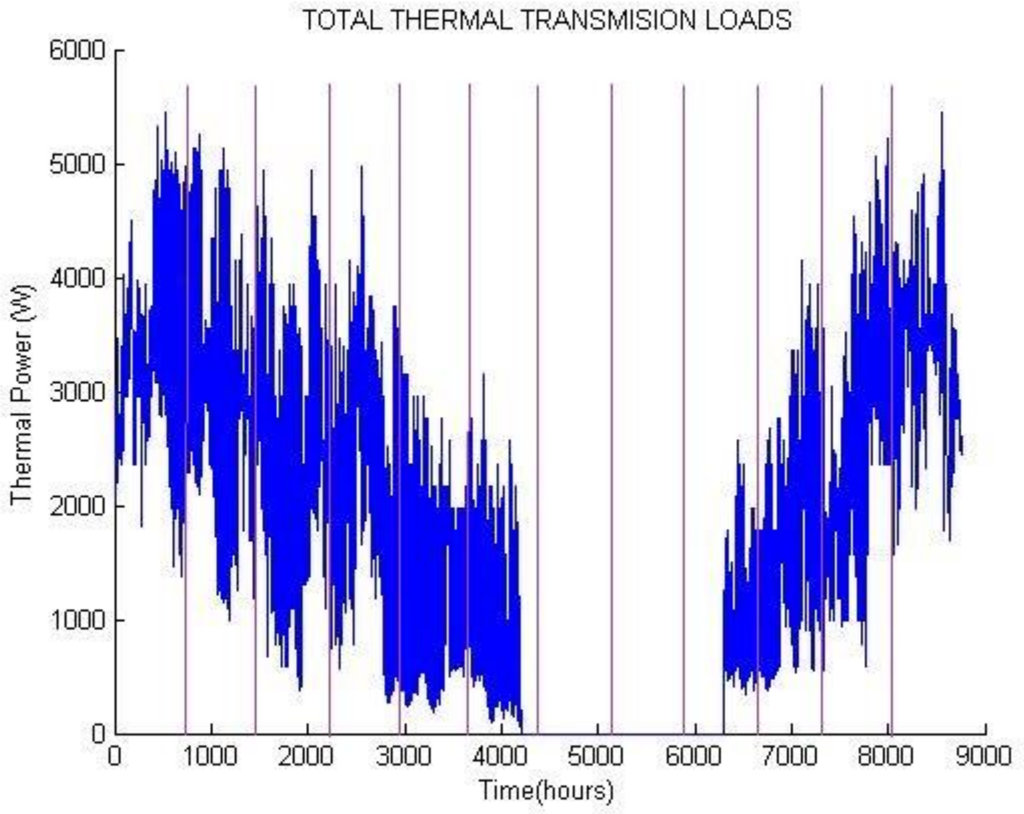


6.4 Total loads

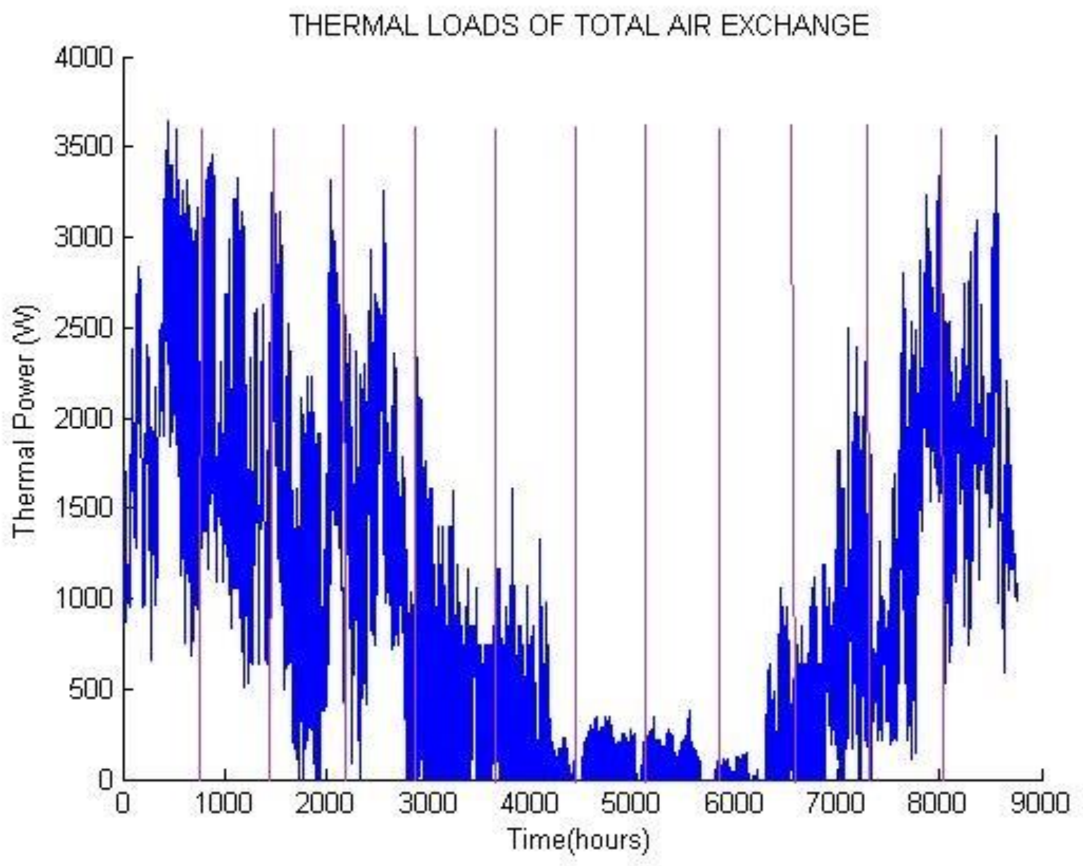
To the end we are going to show the corresponding graphics to the total heat load transmission, the thermal load total exchanges air in each hour of the year.

The last graph will corresponding to the sum of all loads, both transmission and total air exchanges throughout the year.



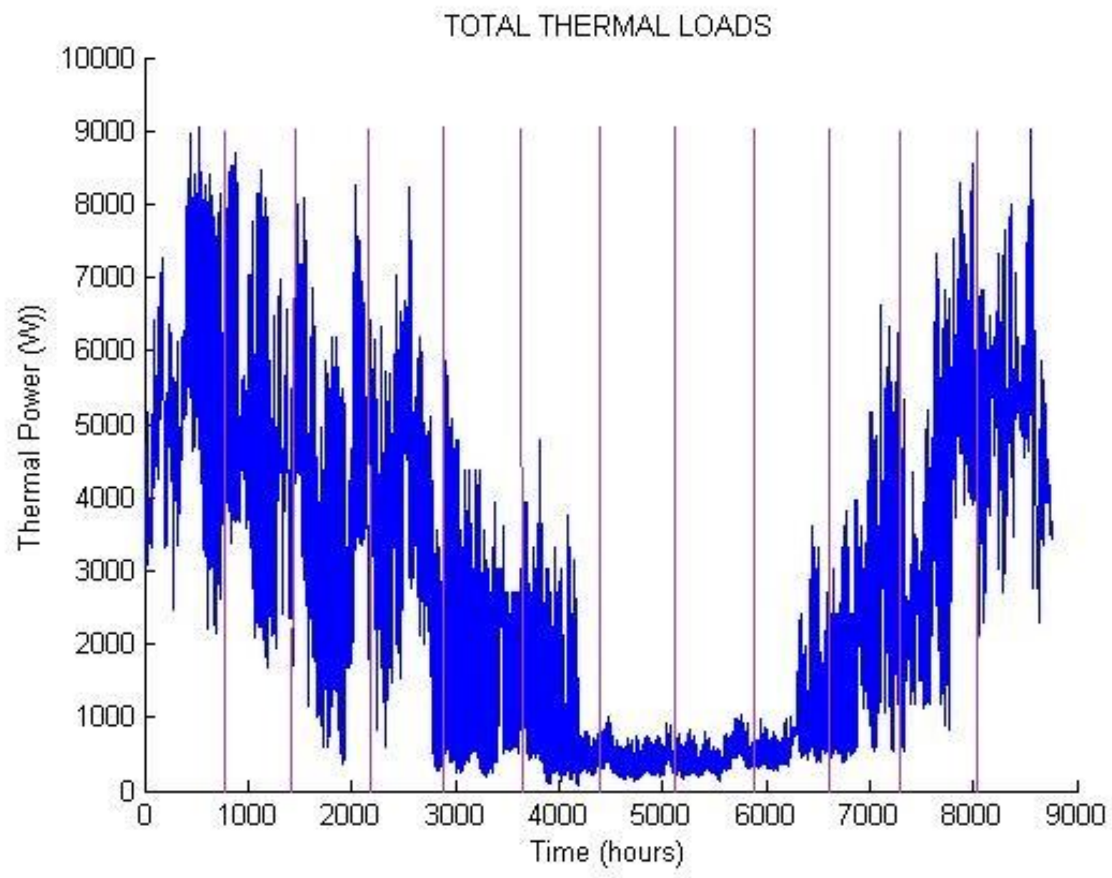
January(1:720h)/February(720:1440h)/March(1440:2160h)/April(2160:2880h)/May(2880:3600h)/June(3600:4320h)/July(4320:5040h)/August(5040:5760h)/ September(5760:6480h)/October(6480:7200h)/November(7200:7920h)/ December(7920:8760h)

A quick study of the transmission load can conclude that the most important for the transmission load is the wall, as the heat transfer area is very large, although the coefficient of heat transfer is not high and the least influence are doors by its reduced transfer area and low overall heat transfer coefficient due to the favorable thermal conductivity pine. The roof would be the second largest contribution to the heat load followed windows, very presently evolved and soil.



January(1:720h)/February(720:1440h)/March(1440:2160h)/April(2160:2880h)/May(2880:3600h)/June(3600:4320h)/July(4320:5040h)/August(5040:5760h)/ September(5760:6480h)/October(6480:7200h)/November(7200:7920h)/ December(7920:8760h)

As shown in the top graph, the total air exchange loads reach maximum values of 3700 W. As is checked, these values correspond to the months of January and December, because those months are those with lower temperatures relative to the rest. The same situations we can see with relative humidities, that is, these two winter months, are those that are higher relative humidities along all year. In the same way, the summer months, namely July and August are the least load air exchange contribute, as they are the hottest and driest months in the community of Madrid.



January(1:720h)/February(720:1440h)/March(1440:2160h)/April(2160:2880h)/May(2880:3600h)/June(3600:4320h)/July(4320:5040h)/August(5040:5760h)/ September(5760:6480h)/October(6480:7200h)/November(7200:7920h)/ December(7920:8760h)

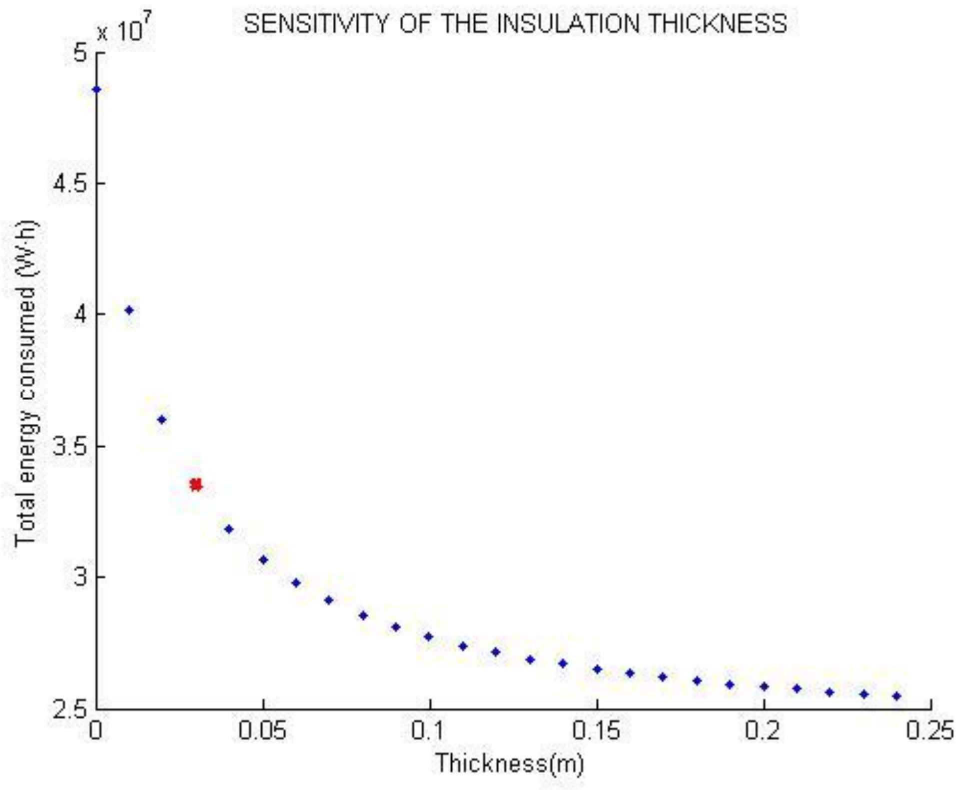
Thanks to the matlab code we have been able to calculate the total thermal loads. In the heating period the quantity is the $19.18MWh$.

As it expected, and as shown in this graph, the total thermal loads for the period of heating, reach their highest values in the months of January and December. The maximum value is placed around the 9000W. The greatest contribution of these values corresponding to the thermal load transmission as ventilation heat loads, compared with transmission are much lower.

7. STUDY OF THE SENSITIVITY OF THE INSULATION THICKNESS

Throughout this section we will study how varies the energy consumed by my house over a year, depending on the thickness of the wall and roof. These vary from a value of 0, up to four times the thickness value. As in section four I have found different thicknesses for wall and roof, I chose as a baseline the thickness of the roof.

This thickness will vary, in the city of Madrid, from a minimum value of 0 to a maximum value of 0.25m, 0.01m in equal intervals. The wall thickness will do the same.

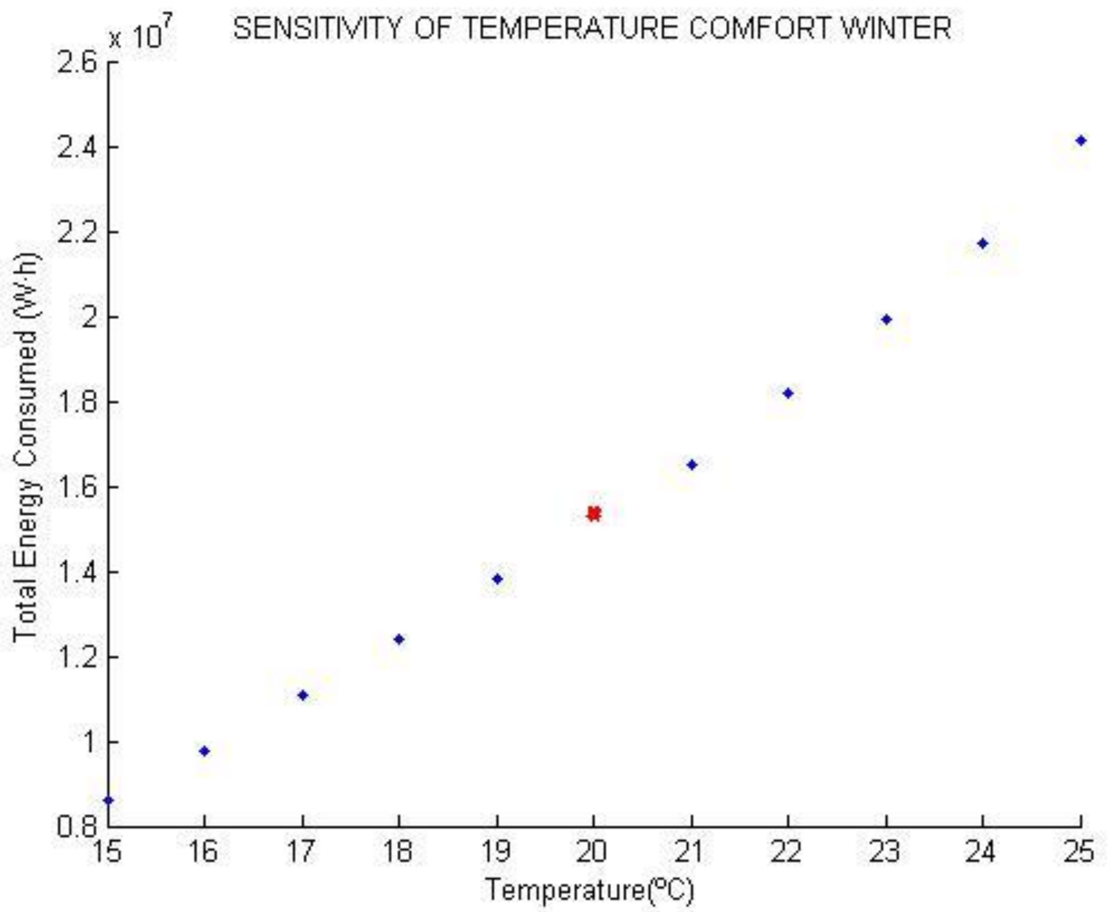


The value in red is the corresponding calculated in section 4, and takes a value of 0.031m, so you can get exactly the value of the overall coefficient of heat transfer boundary indicated by the CTE. Through the graph we can determine that as the thickness of the expanded polystyrene decrease the total energy consumed is increased considerably. From a certain value, close to 0.15m, the energy decreases very little, but the cost increase with insulation thickness increase.

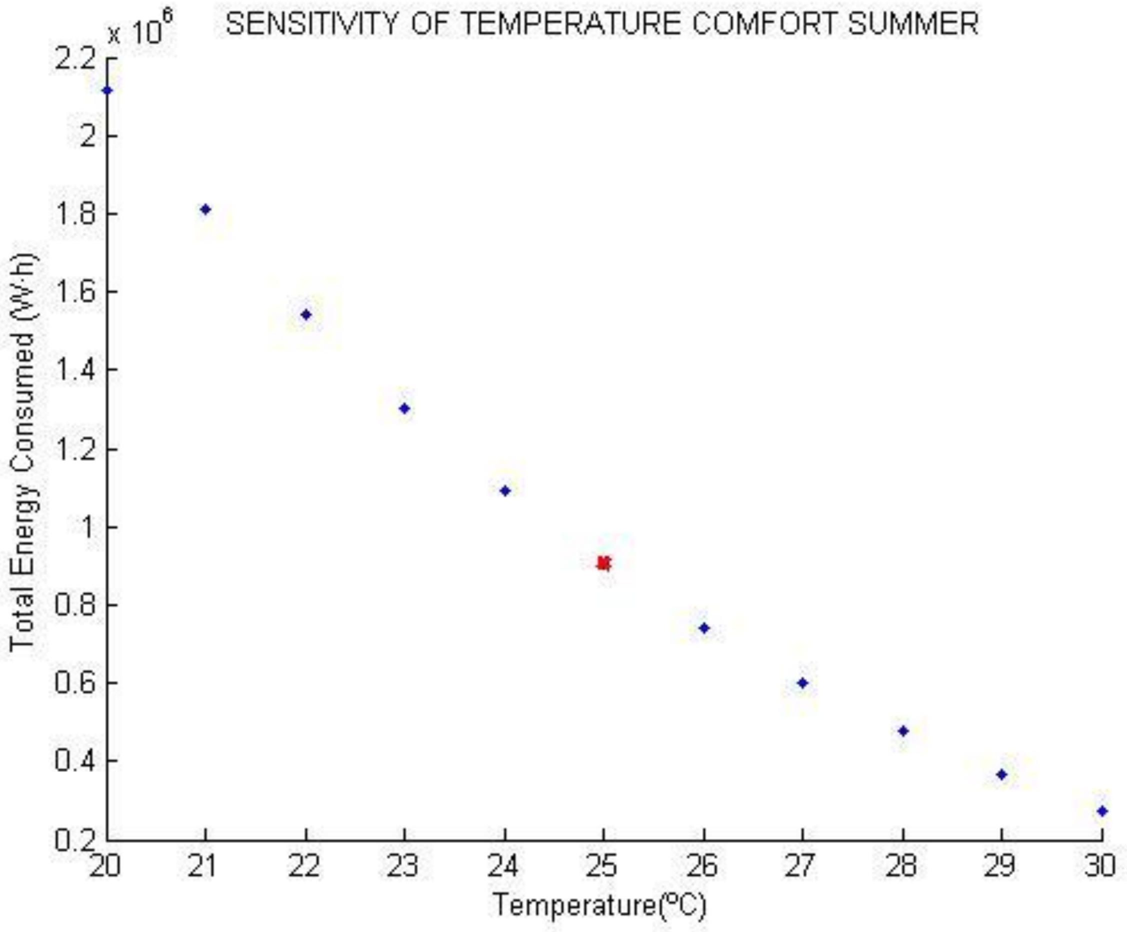
8. SENSITIVITY STUDY OF THE COMFORT TEMPERATURE

Here a first graph for the heating period, the total energy consumed in heating period as a function of the internal temperature is presented. We must remember that the internal temperature of comfort for winter is 20ºC.

The second graph corresponds to the period of cooling. In the latter case the inner temperature of 25 ° C took a value.



As can be seen as we increase our temperature inside the house, we consume more energy, since the difference between the outside temperature and the comfort temperature we want to establish in the interior will be higher. The transmission heat load, which is the sensible load contributed by the temperature difference, is the largest contributor to the calculation of the energy consumed. Hence, the influences are so different if we have one or other comfort temperature.



This time, the problem will evolve differently. As our comfort temperature increases, the energy consumed by my home decrease. As in the previous case, this is because the indoor temperature difference with respect to the outside temperature decreases as temperature increases comfort.

9. HEAT DEMAND ANALYSIS

9.1 Heat demand

The annual heat demand for this building is the sum of all contributories systems to heating that require to operate. Such systems in the case considered are only the radiators. The annual heat demand will be the difference between the average heat consumption and the heat gains during the year.

In this section we show the heat demand quantitatively over 12 months.

In order to calculate the kWh, we will make the average of each month. The following table shows the average consumption of each month:

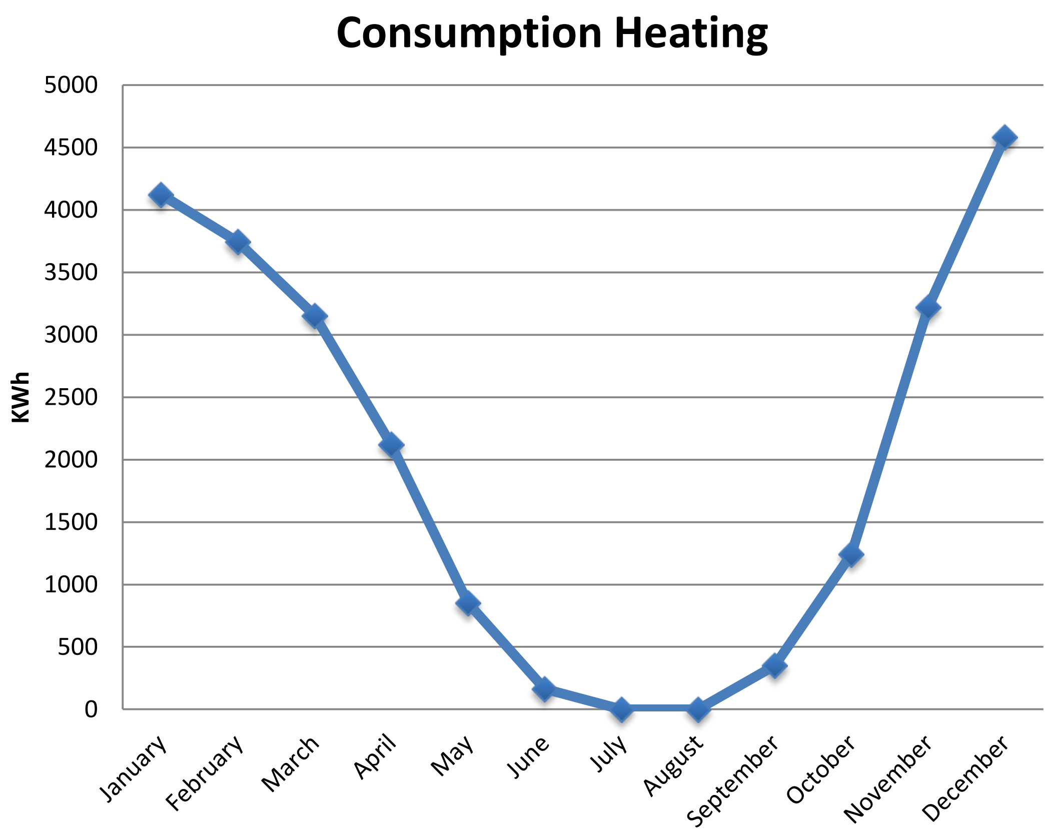


FIGURE 7: Average consumption heating

MONTH	*MWh*
JANUARY	4.124
FEBRUARY	3.743
MARCH	3.154
APRIL	2.120
MAY	0.850
JUNE	0.163
JULY	-
AUGUST	-
SEPTEMBER	0.350
OCTOBER	1.244
NOVEMBER	3.222
DECEMBER	4.583

TABLE 13: Energy consumed

The total energy consumed during the heating period will be worth 19,18 MW ·h. The heating system to meet demand throughout the season should have a power of at least 8.9 kW.

9.2 Heat gains

9.2.1 Internal Loads

The internal loads can be calculated by the sum of three factors, the occupation, the illumination and the hardware. One of the main contributions in this type of thermal loads is the occupants of the dwelling. In the human body an exothermic transformation whose intensity varies according to the individual and team activity occurs. The human body is kept at a temperature of 37ºC with a very small tolerance, but is able to maintain it within wide variations in outdoor temperature, as it is able to expel outwardly more or less important amount of heat developed. This heat, to reach the epidermis, is dissipated by radiation surfaces around him, by convection to the ambient air, and conduction through contact surfaces, although the latter situation is usually negligible.

The values used for the gain due to the occupants are 60 W to 70 W sensible heat and latent heat. These data have been calculated for a 68 kg adult male. In the case of housing under study were considered four people who live there. Defined a factor of simultaneity, so that the thermal load by occupation more real, because not all people will be all hours inside the house. This simultaneity factor has been estimated at 75%. The next equation shows the equation as the calculation carried out on the thermal load, considering the term would be changing as latent heat or sensible. For both cases would be constant throughout the year in the same period.

$$Q_{ocup} = Q_{lat/sen} \cdot f_{sim} \cdot n_{people}$$

Equation 19

$$Q_{ocup(sen)} = 60 \cdot 0.75 \cdot 4 = 180W$$

Another important source of heat in a home is the lighting. The lighting is a source of sensible heat. This heat is emitted by radiation, convection and conduction. It has been estimated illumination depending on the extent and type of area that illuminate, thus in public areas 10 W/m^2 and for other areas 20 W/m^2 will be imposed. The heat input is equal to the electrical output of the lamp. It has also introduced a factor of lighting application, which is not on for 24 hours, reducing their use by 50%. The equation for calculating this heat gain is expressed in the next equation:

$$Q_{ilum} = LEVEL_{ilumination} \cdot f_{sim} \cdot area$$

Equation 20

- LIVINGROOM : $Q_{ilum} = 20 \cdot 0.5 \cdot 47.77 = 477.7\,W$
- BATHROOM: $Q_{ilum} = 20 \cdot 0.5 \cdot 5.36 = 53.6W$
- KITCHEN: $Q_{ilum} = 20 \cdot 0.5 \cdot 11.36 = 113.6W$
- BEDROOM 1: $Q_{ilum} = 20 \cdot 0.5 \cdot 10.33 = 103.3W$
- BEDROOM 2: $Q_{ilum} = 20 \cdot 0.5 \cdot 13.64 = 136.4W$
- BEDROOM 3: $Q_{ilum} = 20 \cdot 0.5 \cdot 10.80 = 108W$
- BEDROOM 4: $Q_{ilum} = 20 \cdot 0.5 \cdot 13.64 = 136.4W$
- HALL: $Q_{ilum} = 10 \cdot 0.5 \cdot 14.74 = 73.7W$

$$Q_{ilum.total} = 1202.7W$$

The last source of internal load studied is due to the use of equipment and utensils of various characteristics. Most of the devices are, in turn, source sensible and latent heat. Electrical appliances emit only latent heat depending on their use, while due to combustion gas appliances produce additional latent heat. These gains in most cases can be reduced by mechanically ventilated hoods which can reduce up to 50% heat input.

The calculation of such profits was made with,

$$Q_{appl} = f_{uso} \cdot Q_{appl}$$

Equation 21

Which has taken the power of the most typical apparatus to be used in a home and multiplied by the average factor of use of that device.

For the layout of the house has conducted a study with different types of appliances:

APPLIANCES	FACTOR OF USE(per hour)	POWER(W)
Fridge	24	300
Vitro ceramic	4	1000
Oven	4	1495
Big TV	12	220
Small TV	12	150
Computer	12	150

TABLE 14: Power appliances per hour

$$Q_{appliances\,TOTAL} = 3315\,W$$

The sum of the internal loads in a day for a total is:

$$Q_{INTERNAL\,LOADS\,TOTAL} = Q_{ocup} + Q_{ilum} + Q_{appl} = 180 + 1202.27 + 3315 = 4697.7\,W$$

9.2.2 Radiation Loads

The intensity of solar radiation is between 1395 W/m^2 on December 21, when the Earth is at perihelion, and 1308 W/m^2 in June, when it is at aphelion. These are the upper and lower limits of solar radiation, and at other times, depending on the month in which it is measured will vary approximately between these limits.

This study will take into account heat gain through glass surfaces as are the various windows of the house. Heat gain through an ordinary glass depends on your geographical location (latitude) of the instant considered and finally on its orientation. Direct, diffuse and reflection: the three forms of radiation are taken into account. The direct component of radiation heat gain originates in the conditioned space only when the window is crossed by sunlight, while the diffuse radiation originates from any heat gain of the position of the window relative to the sun. Generally the glass absorbs a fraction of 5% solar radiation and reflects or transmits the rest. The magnitude of heat reflected and transmitted depends on the angle of incidence and the angle formed by the normal to the crystal direction of the sun. Increasing this angle, the reflected heat increases and decreases heat transmitted.

To calculate the radiation incident on the house first thing you need to consult is its geographical location. It is located at a latitude of 40.35 degrees and a length of -4.002 degrees. Another aspect to consider is the inclination is the inclination of the wall from the floor that being the windows, is 90 degrees. It will be calculated for each day decline of the year.

Radiation data is typically recorded to a horizontal plane and in the form of global radiation, without distinguishing direct and diffuse components. The transformation to the inclined plane, in the case of the windows of the apartment is 90 degrees through geometric relationships and form factors that require knowing where the radiation comes. Determine how much radiation is diffuse, how it is reflected and the direction of origin using for this different correlations and models sky. Sky model that has been used for calculations of radiation is isotropic model. These models consider that the diffuse radiation has no directional component, all the diffuse radiation is isotropic.

We take the maximum load of each curve as a function of different orientation.

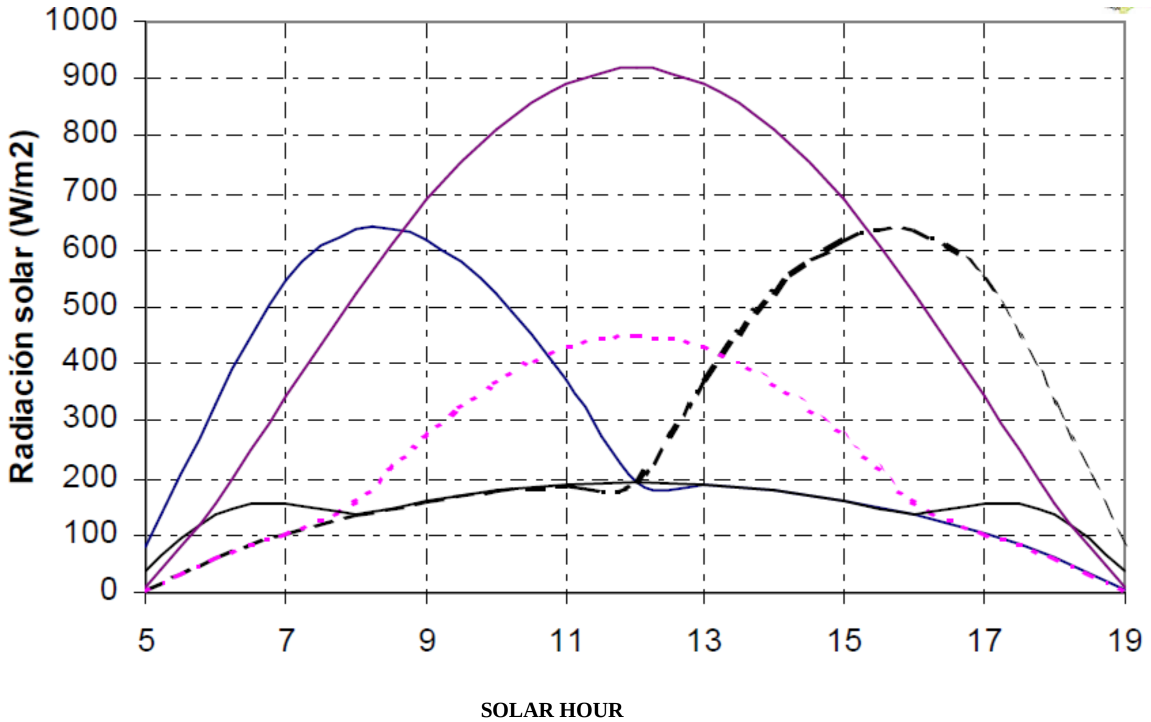


FIGURE 8 : Radiation solar

Using these graphics, these values are:

$I_{NORTH} = 200\ W/m^2$

$I_{SOUTH} = 450\ W/m^2$

$I_{EAST} = 600 W/m^2$

$I_{WEST} = 600\ W/m^2$

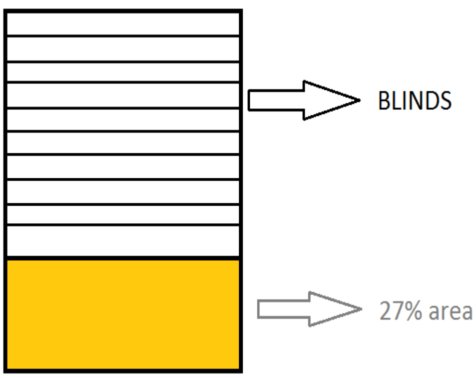


FIGURE 9 : Window blinds

We have to determine the correction factor depending on the materials we can find:

- double glazed $\longrightarrow$ f_c =0.9
- curtains $\longrightarrow$ f_c =0.6
- blinds $\longrightarrow$ f_c =0.27

$$Q_{radiation} = (\sum I_{orintation} \cdot A_{window}) \cdot f_{correction\ factor}$$

Equation 22

Using these values, the table of the glazed surfaces and equation number 21 we get:

- LIVINGROOM : $Q_{radiaction} = 0.27 \cdot [(450 \cdot 6.05) + (600 \cdot 7.11) + (600 \cdot 6.05)] \cdot 0.27 = 774.08\ W$
- BATHROOM: $Q_{radiaction} = 0.27 \cdot [(600 \cdot 0.36)] \cdot 0.27 = 15.74\ W$
- KITCHEN: $Q_{radiaction} = 0.27 \cdot [(600 \cdot 2.31)] \cdot 0.27 = 101.03\ W$
- BEDROOM 1: $Q_{radiaction} = 0.27 \cdot [(600 \cdot 2.59)] \cdot 0.27 = 113.6\ W$
- BEDROOM 2: $Q_{ilum} = 0.27 \cdot [(200 \cdot 2.59)] \cdot 0.27 = 37.76W$
- BEDROOM 3: $Q_{radiaction} = 0.27 \cdot [(600 \cdot 2.59)] \cdot 0.27 = 113.6\ W$
- BEDROOM 4: $Q_{radiaction} = 0.27 \cdot [(600 \cdot 2.59)] \cdot 0.27 = 113.6\ W$
- HALL : doesn't have windows

$$Q_{radiation\ TOTAL} = 1269.41\ \mathrm{W}$$

As I said in the previous pages the quantity is the 19.18MWh during the heating period. If we include the $Q_{radiation\ TOTAL}$ and the $Q_{internal\ loads\ TOTAL}$ we got 5957.11 W to reduce.

Below I have detailed graphically the contribution of each internal font:

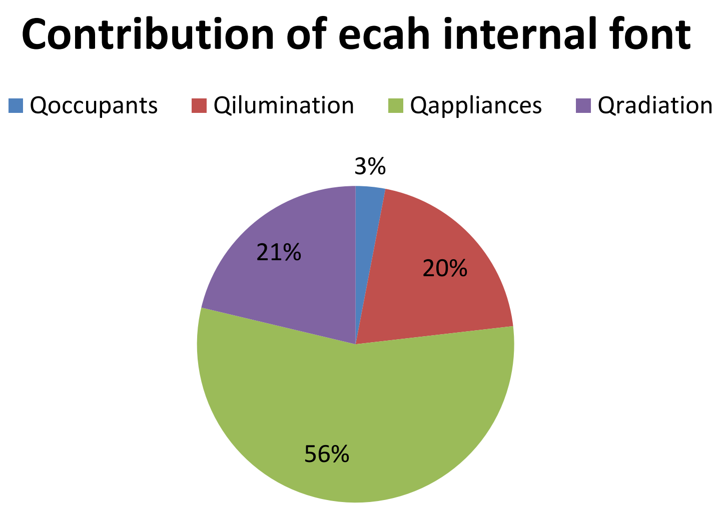


FIGURE 10 : Contribution of each internal font

More than fifty% of internal loads corresponds to appliances. The following sources are contributing more heat radiation and lighting.

Each internal source is composed of the sum of small contributions, which are detailed below:

- Gain due to the illumination:

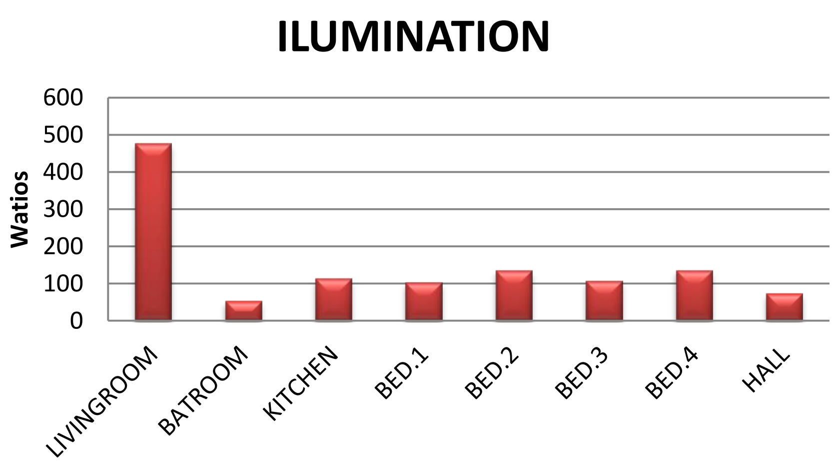


FIGURE 11: Illumination

- Gain due to the appliances:

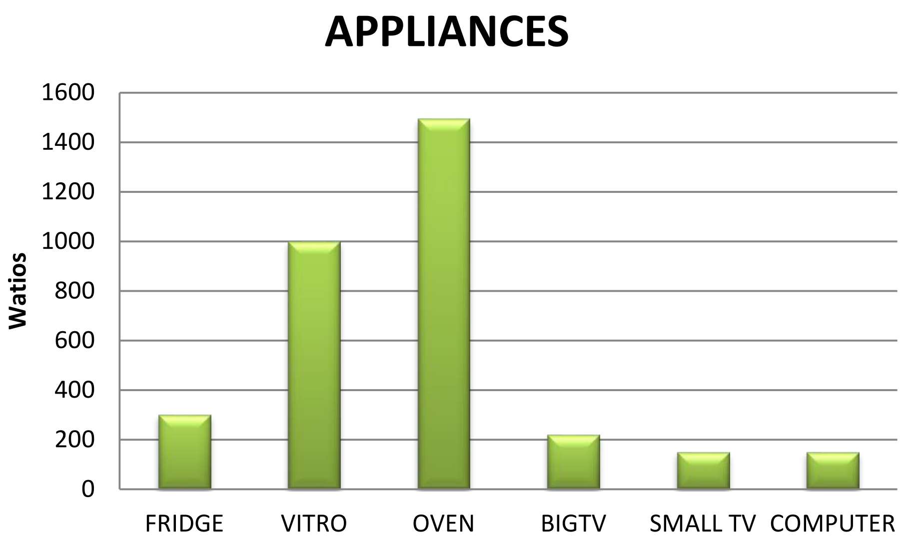


FIGURE 12 : Appliances

- Gain due to the radiation:

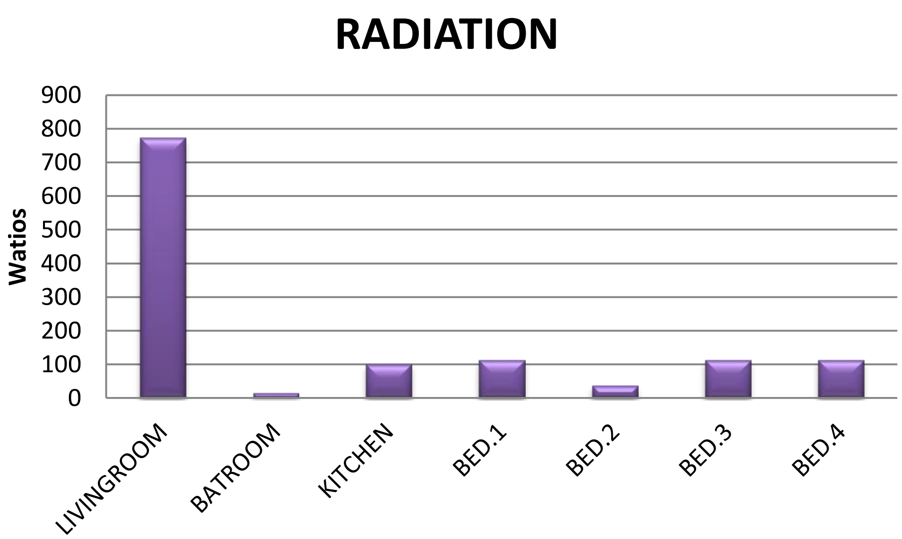


Figure 13 : Radiation

9.3 Total heat demand

The annual heat demand for this building is the sum of all contributories systems to heating that require to operate. Such systems in the case considered are only the radiators. The annual heat demand will be the difference between the average heat consumption and the heat gains during the year. The annual heat demand can be calculated by following expression:

$$Q_{hs} = \frac{\sum Q_h}{\eta_1 \cdot \eta_2 \cdot \eta_3 \cdot \eta_4}$$

Equation 23

Where

Q_h: – the heat demand for room, W;

η_1 – heat system regulation effectiveness coefficient;

η_2 – heat source effectiveness coefficient;

η_3 – main heating system pipes insulation effectiveness coefficient;

η_1– the hydraulic balancing of heat system effectiveness coefficient.

Type of regulation	Heating network	Kid of fuel			Electric
		gas	liquid	solid	
Hand regulation	0.9	0.8	0.75	0.60	0.90
Automatic regulation	1	0.94	0.87	0.85	1.00

TABLE 15 : The coefficient of efficiency

Type of thermal isolation	Effectiveness coefficient, η_3
New heating system pipes thermal isolation	0.97
Old heating system thermal isolation	0.9
Without thermal isolation	0.7

TABLE 16: Type of thermal insolation

*In our case, these variables take the next values:

- $\eta_1 = 0.95$ (Heating system regulation due to outdoor temperature and/or heat devices with thermostatic waves)
- $\eta_2 = 1$ (Heating network, automatic regulation)
- $\eta_3 = 0.9$ (New pipes, high insulation effectiveness coefficient)
- $\eta_4 = 0.92$ (Heat system without balancing waves and circulation pump)

The heat demand for the house Q_h can be calculated by following expression:

$$Q_h = Q_{en} - \eta_0 \cdot Q_{hg}$$

Equation 24

Where:

Q_{en}-heat demand to compensate envelopes heat losses , kWh;

η_0-heat gains use efficiency coefficient;

Q_{hg}-heat gains, kWh.

*In our case, these variables take the next values:

$\eta_0 = 0.8$ (Heating system controlled according outdoor temperature, thermostats)

The heat demand to compensate envelopes heat losses can be calculated by following simplified expression:

$$Q_{en} = H_{en} \cdot (\theta_i - \theta_{em}) \cdot t \cdot 24 \cdot 10^{-3}$$

Equation 25

Where:

H_{en}-heat loss coefficient through envelopes, W/K.

θ_i-indoor design temperature, ºC;

θ_{em}-external average temperature of calculation (heating season) period, ºC;

t-duration of the heating season in days.

*In our case, these variables take the next values:

$\theta_i = 20$ºC

$\theta_{em} = 8.27ºC$

t= 255 days

The heat gains Q_{hg} are calculated in two parcels. One refers to the internal heat gains and the other to heat gains due to sun light. The heat gains can be calculated by following expression:

$$Q_{hg} = Q_{ig} + Q_{sg}$$

Equation 26

These calculations have been made in section 9.2. So we all this information, we can get that the heat consumption is:

	Qen(kWh)	Qhg(kWh)	Qh(kWh)
HOUSE	19180.20	5957.11	14414.51

TABLE 17: Heat consumption

Below will show results in different graphs, and the last of it we see in the same graph the heat consumed by housing and heat will really have to pay to our electric company, and we must subtract the internal loads.

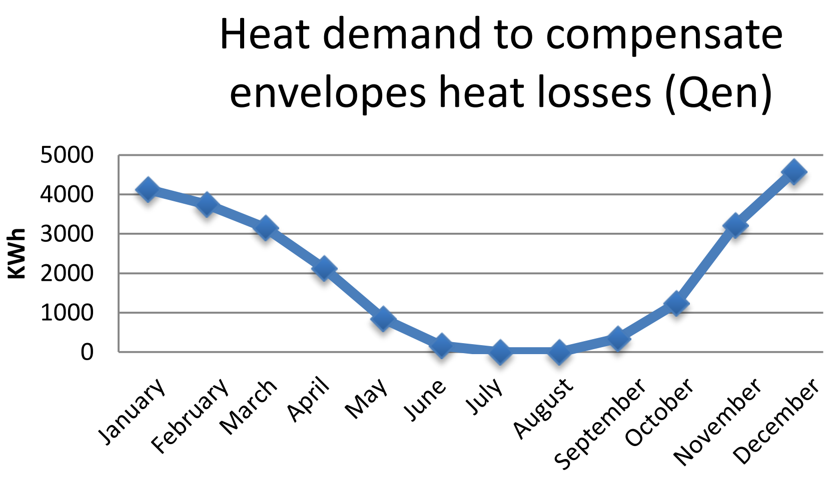


FIGURE 14: Heat demand to compensate envelopes heat losses

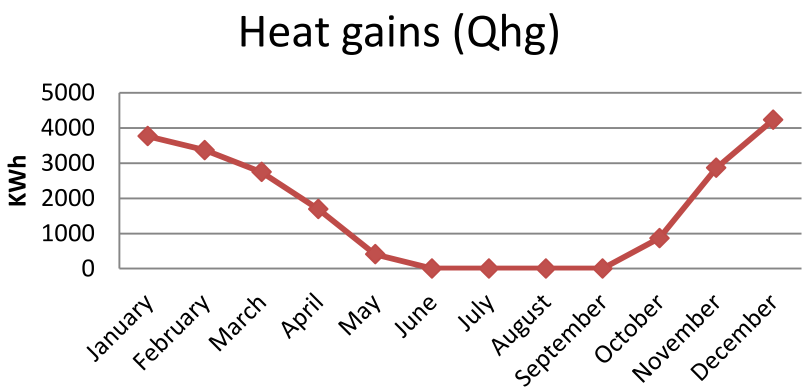


Figure 15 : Heat gains

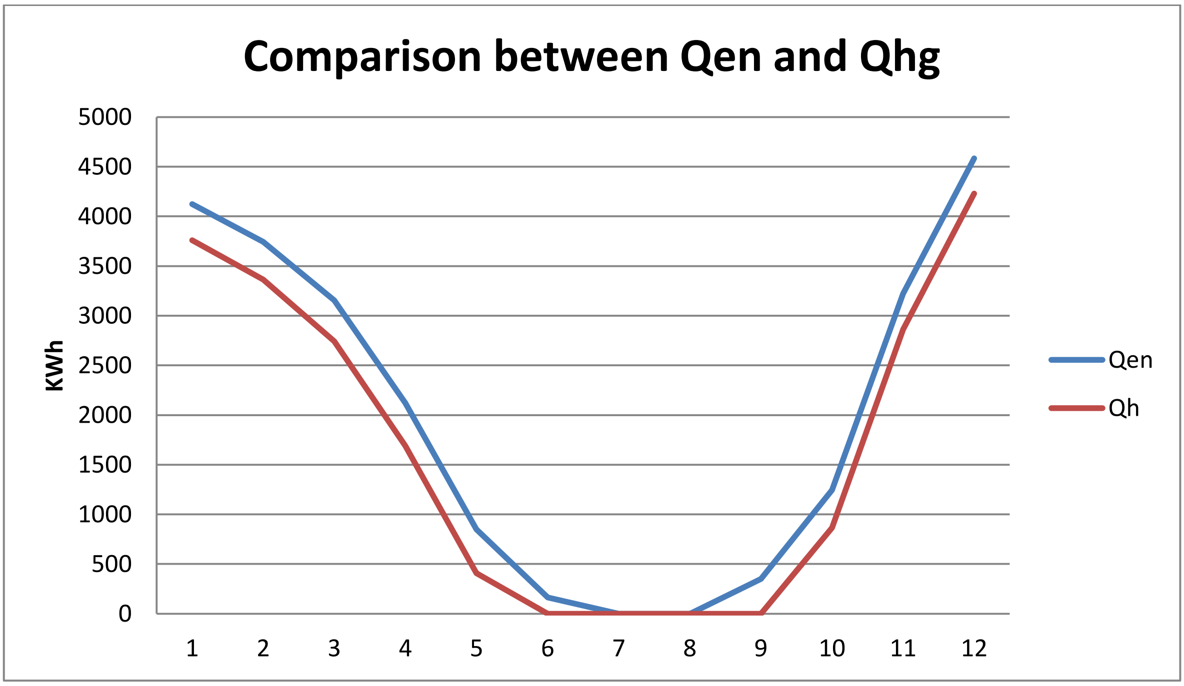


Figure 16 : Comparison between Qen and Qhg

9.4 Cost for heat for heating

In this last section we will calculate the annual cost of heating. Also I will calculate the savings that will make, thanks to internal loads.

In the next table we can find the rates of natural gas:

type of consumption	Consumption kWh/year	recommended rate	fixed term €/month	Variable term €/kWh
Low consumption	<5000	Basic gas	4.36	0.05533309
medium consumption	<15000	Optimal gas	8.84	0.04845909
high medium consumption	>=15500	Family gas	10.70	0.04652073
High consumption	50000-100000	Energy plan 3.3	54.22	0.050973
consumption exceeds a 100000 kWh	<100000	Energy plan 3.4	80.97	0.047723

TABLE 18 : Rates of natural gas

Using the table above, the heat cost in Madrid will be:

-Variable term: 698.51€

-Fix term: 79.56€

10. CONCLUSIONS

In this final work, we spoke about the mucroclimate characteristics in a house placed in Madrid. We made the calculation of the heating, and after we try to get the comfort environment which is needed for a unfamiliar house.

There are few conclusions can be inferred from the draft climate of housing. With the energy situation, has been explained as part of the introduction, the clear of the need for these feasibility studies weatherization projects. These studies should not be only theoretical and engineering level as part of a constructive process of homeownership so that equipment can be dimensioned to report a perfect performance and a constant interior comfort, which is what they really are designed. The study should be an economic and environmental dimension, which is no less important than mentioned above.

Of the three contributions to the overall thermal load conditions have been used in heating, the thermal load and the thermal load transmission by ventilation have formed about 80% of the total heat load in this period, while 20% remaining due to infiltration, infiltration can conclude that these have minor terms of both transmission and ventilation when insulation thicknesses are large (10 to 15 cm). If the insulation thickness is smaller (actual thickness of the apartment: 5 cm) infiltration and ventilation are not growing, and that at no time dependent insulation, but the transmission load increase slightly to be more sheltered housing against cold, so that in this type of thermal load, the thickness of the insulation would be the only variation in the load transmission, the other remaining constant.

In the case of climate conditions will have more components of the thermal load on heating. The biggest contribution is provided by the so-called internal load. This internal load is due to the life within the housing, operation of equipment, lighting and other elements that emit heat inside. Once this internal contribution calculated it can be said that depends on what you consider the person making the calculation that will be on providing heat in the house. It may not be accurate this calculation because it is not known how long it will take an appliance on the user's home, so this contribution to the overall thermal load is an estimate of what would be a general operation of appliances and equipment housing, and a significant influence on the overall thermal load, which should not be disproportionately without breaking and yet without getting scarce.

The other difference in heating conditions is the thermal load due to radiation. Once the incident radiation at different orientations of the house, following the technical building code has been calculated. There is a difference in the amount of heat gained by the different faces of housing being the smallest north south orientation and further guidance.

11. APPENDIX

```
%I define my array variables

h=mm(:,1);
t=mm(:,2)+273;
chi=mm(:,3)/100;

%representation of the relative humidity and temperature
% figure(1)=plot(h,t);
% ylabel ('Temperature (K)')
% xlabel ('Time (hours)')
% title ( ' TEMPERATURE THROUGHOUT THE YEAR IN MADRID' )

% figure(2)=plot(h,chi);
% xlabel ('Time (hours)')
% title ( ' RELATIVE HUMIDITY TROUGHTOUT THE YEAR IN MADRID' )

% I define comfort temperatures and humidities
tiverano=25+273;
tiinvierno=20+273;
hri=40/100;
hrv=60/100;

% COVER

%convection resistances vary in summer and winter to calculate the
thickness of ep we'll do the most unfavorable case that is in  winter


rseci=0.04;
rsici=0.1;
epec=0;
espesorescub=[0.05 0.25 epec 0.02];
kcubierta=[1.16 1.39 0.04 0.3];
rconduccioncub=0;
ulimcub=0.49;


for i=1:4
rconduccioncub=rconduccioncub+(espesorescub(i)/kcubierta(i));
end

Rtcub=rsici+rseci+rconduccioncub;
epec=((1/ulimcub)-Rtcub)*0.04;

% OUTER WALL
%it  does not change whether it is summer or winter

rseme=0.04;
rsime=0.13;
epeme=0;
espesoresme=[0.02 0.09 epeme 0.09 0.02];
kme=[1.14 0.52 0.04 0.52 0.3];
rconduccionme=0;
```

```
ulimme=0.66;

for i=1:5
rconduccionme=rconduccionme+(espesoresme(i)/kme(i));
end

Rmet=rsime+rseme+rconduccionme;

epeme =((1/ulimme)-Rmet)*0.04;


% THERMAL LOADS ON THE COVER

% HEATING

salon=44.77;
bano=5.63;
cocina=11.36;
d1=10.33;
d2=13.64;
d3=10.80;
d4=15;
vestibulo=14.74;

qsic=(8760:1);
qbic=(8760:1);
qcic=(8760:1);
qd1ic=(8760:1);
qd2ic=(8760:1);
qd3ic=(8760:1);
qd4ic=(8760:1);
qvic=(8760:1);
qsc=(8760:1);
qbc=(8760:1);
qcc=(8760:1);
qd1c=(8760:1);
qd2c=(8760:1);
qd3c=(8760:1);
qd4c=(8760:1);
qvc=(8760:1);
qtcinvierno=(8760:1);
qtcverano=(8760:1);

% hold on
for i=1:8760
        qsic(i)=(salon*ulimcub*(tiinvierno-t(i)));
        qbic(i)=(bano*ulimcub*(tiinvierno-t(i)));
        qcic(i)=(cocina*ulimcub*(tiinvierno-t(i)));
        qd1ic(i)=(d1*ulimcub*(tiinvierno-t(i)));
        qd2ic(i)=(d2*ulimcub*(tiinvierno-t(i)));
        qd3ic(i)=(d3*ulimcub*(tiinvierno-t(i)));
        qd4ic(i)=(d4*ulimcub*(tiinvierno-t(i)));
        qvic(i)=(vestibulo*ulimcub*(tiinvierno-t(i)));

qtcinvierno(i)=qsic(i)+qbic(i)+qcic(i)+qd1ic(i)+qd2ic(i)+qd3ic(i)+qd4i
c(i)+qvic(i);
end
```

```
for i=1:8760
    if qtcinvierno(i)<0
        qtcinvierno(i)=0;
    end
end

for i=4200:6300
    qtcinvierno(i)=0;
end
hold on
figure (3)=plot(h,qtcinvierno,'b');
ylabel ('Termal Power (W)')
xlabel ('Time(hours)')
title ( 'ROOF THERMAL TRASMISSION LOADS' )

%cooling

for i=1:8760
    qsc(i)=(salon*ulimcub*(t(i)-tiverano));
    qbc(i)=(bano*ulimcub*(t(i)-tiverano));
    qcc(i)=(cocina*ulimcub*(t(i)-tiverano));
    qd1c(i)=(d1*ulimcub*(t(i)-tiverano));
    qd2c(i)=(d2*ulimcub*(t(i)-tiverano));
    qd3c(i)=(d3*ulimcub*(t(i)-tiverano));
    qd4c(i)=(d4*ulimcub*(t(i)-tiverano));
    qvc(i)=(vestibulo*ulimcub*(t(i)-tiverano));

qtcverano(i)=qsc(i)+qbc(i)+qcc(i)+qd1c(i)+qd2c(i)+qd3c(i)+qd4c(i)+qvc(
i);

end

for i=1:8760
    if qtcverano(i)<0
        qtcverano(i)=0;
    end
end
%
%
for i=1:4200
    qtcverano(i)=0;
end

for i=6300:8760
    qtcverano(i)=0;
end
figure(3)=plot(h,qtcverano,'r')
hold off



%outwall thermal loads

msalon=44.33;
mbano=3.86;
mcocina=10.41;
md1=14.68;
md2=19;
md3=9.63;
```

```
md4=20.63;
mvestibulo=3.91;
qsim=(8760:1);
qbim=(8760:1);
qcim=(8760:1);
qd1im=(8760:1);
qd2im=(8760:1);
qd3im=(8760:1);
qd4im=(8760:1);
qvim=(8760:1);
qsm=(8760:1);
qbm=(8760:1);
qcm=(8760:1);
qd1m=(8760:1);
qd2m=(8760:1);
qd3m=(8760:1);
qd4m=(8760:1);
qvm=(8760:1);
qtmverano=(8760:1);
qtminvierno=(8760:1);

%heating
 hold on
for i=1:8760
    qsim(i)=(msalon*ulimme*(tiinvierno-t(i)));
    qbim(i)=(mbano*ulimme*(tiinvierno-t(i)));
    qcim(i)=(mcocina*ulimme*(tiinvierno-t(i)));
    qd1im(i)=(md1*ulimme*(tiinvierno-t(i)));
    qd2im(i)=(md2*ulimme*(tiinvierno-t(i)));
    qd3im(i)=(md3*ulimme*(tiinvierno-t(i)));
    qd4im(i)=(md4*ulimme*(tiinvierno-t(i)));
    qvim(i)=(mvestibulo*ulimme*(tiinvierno-t(i)));

qtminvierno(i)=qsim(i)+qbim(i)+qcim(i)+qd1im(i)+qd2im(i)+qd3im(i)+qd4i
m(i)+qvim(i);

end
for i=1:8760
    if qtminvierno(i)<0
        qtminvierno(i)=0;
    end
end

for i=4200:6300
    qtminvierno(i)=0;
end
% figure(4)=plot(h,qtminvierno,'b');
% ylabel ('Termal Power (W)')
% xlabel ('Time(hours)')
% title ( 'OUTER WALL THERMAL TRASMISSION LOADS' )

%cooling

for i=1:8760
    qsm(i)=(msalon*ulimme*(t(i)-tiverano))
```

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